

“ON INTERNATIONAL ENVIRONMENTAL POLICY AND  
TRADE LINKAGE  
The Importance of Trade Ties and Market Structure in Determining  
the Nature of International Cooperation.”

by

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# Abstract

This thesis extends the literature on trade-linked international environmental policy by quantifying the effects of collective taxes on polluting intermediate inputs under varying trade, market structure and labour market assumptions. Using a CGE model augmented to include emissions from intermediate inputs, I simulate the effects of coordinated and harmonized environmental taxes on output, trade, and market structure. The main objectives are to ascertain whether free trade improves regulatory policy outcomes, and to demonstrate how market structure and the relative size of trading partners affect policy responses. To this end, I consider three cases: (a) asymmetric regions competing under perfect competition (b) asymmetric regions competing under imperfect competition and (c) symmetric regions competing under imperfect competition. Using Canada-EU and NAFTA-EU trade to represent asymmetric and symmetric trade ties, the results reveal the following: When regions are asymmetric, free trade unambiguously improves regulatory outcomes for the EU, but yields mixed results for Canada. In addition, regulatory costs are lower when trading partners are symmetric. However, free trade can result in perverse outcomes. For asymmetric regions, output and market structure changes are stronger under imperfect competition, and in the presence of real wage unemployment. Results also suggest that aggregate trade flows are not very sensitive to environmental taxes but are sensitive to changes in border taxes. Finally, welfare effects do not follow a predictable pattern because they partly depend on market structure changes.

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# Dedication

*To my Lord and Savior, Jesus Christ*

“because of Your great love we are not consumed, for Your compassions never fail.

They are new every morning; great is Your faithfulness”

(Lamentations 3:22-23)

# Contents

|                                                                         |            |
|-------------------------------------------------------------------------|------------|
| <b>Abstract</b>                                                         | <b>i</b>   |
| <b>Acknowledgments</b>                                                  | <b>ii</b>  |
| <b>Dedication</b>                                                       | <b>iii</b> |
| <b>List of Tables</b>                                                   | <b>ix</b>  |
| <b>List of Tables</b>                                                   | <b>xi</b>  |
| <b>1 Introduction</b>                                                   | <b>1</b>   |
| 1.1 Background and Motivation . . . . .                                 | 1          |
| 1.2 Objectives . . . . .                                                | 6          |
| 1.3 Methodological Approach . . . . .                                   | 6          |
| 1.4 Research Contribution . . . . .                                     | 7          |
| 1.5 Results and Findings . . . . .                                      | 8          |
| 1.6 Structure of Thesis . . . . .                                       | 9          |
| <b>2 Literature Review</b>                                              | <b>10</b>  |
| 2.1 Introduction . . . . .                                              | 10         |
| 2.2 Environmental Policy Cooperation and<br>Trade Linkage . . . . .     | 11         |
| 2.3 Environmental Tax Design . . . . .                                  | 14         |
| 2.3.1 Optimal Environmental Tax Design . . . . .                        | 15         |
| 2.3.2 Strategic Motives and Environmental Tax Design . . . . .          | 18         |
| 2.4 Approaches to Cooperation: Harmonization vs. Coordination . . . . . | 20         |
| 2.4.1 Policy Coordination . . . . .                                     | 20         |

|          |                                                              |           |
|----------|--------------------------------------------------------------|-----------|
| 2.4.2    | Policy Harmonization . . . . .                               | 22        |
| 2.5      | Environmental Taxes under Perfect Competition . . . . .      | 25        |
| 2.6      | Environmental Taxes under Imperfect<br>Competition . . . . . | 30        |
| 2.7      | Summary and Conclusion . . . . .                             | 33        |
| <b>3</b> | <b>Research Methodology and Data</b>                         | <b>36</b> |
| 3.1      | Introduction . . . . .                                       | 36        |
| 3.2      | Background to CGE Modelling . . . . .                        | 37        |
| 3.2.1    | Theoretical Foundations . . . . .                            | 38        |
| 3.2.2    | Historical Underpinnings . . . . .                           | 39        |
| 3.3      | The Process of CGE Modeling . . . . .                        | 43        |
| 3.3.1    | Production and Consumption Nesting . . . . .                 | 44        |
| 3.3.2    | Functional Forms . . . . .                                   | 44        |
| 3.3.3    | Treatment of International Trade . . . . .                   | 49        |
| 3.3.4    | Macro Closure . . . . .                                      | 50        |
| 3.4      | Model Extensions . . . . .                                   | 52        |
| 3.4.1    | Air Emissions . . . . .                                      | 53        |
| 3.4.2    | Environmental Tax Design . . . . .                           | 54        |
| 3.4.3    | Production Nesting . . . . .                                 | 55        |
| 3.4.4    | Regional Utility with Disutility from Pollution . . . . .    | 57        |
| 3.4.5    | Competitiveness . . . . .                                    | 57        |
| 3.5      | Data and Calibration . . . . .                               | 58        |
| 3.5.1    | Data . . . . .                                               | 58        |
| 3.5.2    | Calibration and Parameterization . . . . .                   | 60        |
| 3.5.3    | Market Structure . . . . .                                   | 61        |

|          |                                                                                     |           |
|----------|-------------------------------------------------------------------------------------|-----------|
| 3.5.4    | Emissions Data . . . . .                                                            | 61        |
| 3.6      | Model Implementation . . . . .                                                      | 62        |
| 3.7      | Conclusion and Limitations of Methodology . . . . .                                 | 62        |
| <b>4</b> | <b>ENVIRONMENTAL POLICY COOPERATION AND TRADE</b>                                   |           |
|          | <b>The Case of Asymmetric Regions and Perfect Competi-</b>                          |           |
|          | <b>tion</b>                                                                         | <b>66</b> |
| 4.1      | Introduction . . . . .                                                              | 66        |
| 4.2      | The Model . . . . .                                                                 | 71        |
| 4.2.1    | Production . . . . .                                                                | 71        |
| 4.2.2    | Final Demand . . . . .                                                              | 79        |
| 4.2.3    | Private Household Demand . . . . .                                                  | 81        |
| 4.2.4    | Prices . . . . .                                                                    | 83        |
| 4.2.5    | Macro Closure . . . . .                                                             | 86        |
| 4.2.6    | Equilibrium Conditions . . . . .                                                    | 86        |
| 4.3      | Application, Chapter Specific Data and<br>Calibration . . . . .                     | 87        |
| 4.4      | Simulation Design . . . . .                                                         | 89        |
| 4.5      | Results and Discussion . . . . .                                                    | 91        |
| 4.5.1    | Effects of Environmental Taxes in the Presence of Real Wage<br>Rigidities . . . . . | 92        |
| 4.5.2    | Trade Effects in the Presence of Real Wage Rigidities . . . . .                     | 96        |
| 4.5.3    | Welfare Effects in the Presence of Real Wage Rigidities . . . . .                   | 97        |
| 4.5.4    | Effects of Environmental Taxes in the Presence of Flexible Wages                    | 102       |
| 4.5.5    | Trade Effects under Flexible Wage Closure . . . . .                                 | 104       |
| 4.5.6    | Welfare Effects under the Flexible Wage Closure . . . . .                           | 105       |
| 4.6      | Conclusion . . . . .                                                                | 108       |

## 5 ENVIRONMENTAL POLICY COOPERATION AND TRADE

### The Case of Asymmetric Regions and Imperfect Competition 114

|       |                                                                                                |     |
|-------|------------------------------------------------------------------------------------------------|-----|
| 5.1   | Introduction . . . . .                                                                         | 114 |
| 5.2   | Model Extension . . . . .                                                                      | 118 |
| 5.2.1 | Production and Supply . . . . .                                                                | 119 |
| 5.2.2 | Supply . . . . .                                                                               | 122 |
| 5.2.3 | Demand . . . . .                                                                               | 124 |
| 5.2.4 | Private Household Demand . . . . .                                                             | 126 |
| 5.2.5 | Macro Closure . . . . .                                                                        | 129 |
| 5.2.6 | Equilibrium Conditions . . . . .                                                               | 129 |
| 5.3   | Application, Chapter Specific Data and Calibration . . . . .                                   | 129 |
| 5.4   | Simulation Design . . . . .                                                                    | 130 |
| 5.5   | Simulation Results and Discussion . . . . .                                                    | 130 |
| 5.5.1 | Effects of Collective Environmental Taxes in the Presence of<br>Real Wage Rigidities . . . . . | 131 |
| 5.5.2 | Effects of Environmental Taxes When Wages are Flexible . . . . .                               | 142 |
| 5.6   | Conclusion . . . . .                                                                           | 151 |

## 6 ENVIRONMENTAL POLICY COOPERATION AND TRADE

### The Case of Symmetric Regions and Imperfect Competition 155

|       |                                                                                                |     |
|-------|------------------------------------------------------------------------------------------------|-----|
| 6.1   | Introduction . . . . .                                                                         | 155 |
| 6.2   | Model Extension . . . . .                                                                      | 158 |
| 6.3   | Application, Chapter Specific Data and<br>Calibration . . . . .                                | 158 |
| 6.4   | Simulation Results and Discussion . . . . .                                                    | 161 |
| 6.4.1 | Effects of Collective Environmental Taxes in the Presence of<br>Real Wage Rigidities . . . . . | 161 |

|          |                                                                                       |            |
|----------|---------------------------------------------------------------------------------------|------------|
| 6.4.2    | Effects of Collective Environmental Taxes in the Presence of Flexible Wages . . . . . | 171        |
| 6.5      | Conclusion . . . . .                                                                  | 179        |
| <b>7</b> | <b>MARKET STRUCTURE AND THE NATURE OF TRADE TIES</b>                                  |            |
|          | <b>Implications for Collective Environmental Policy Outcomes</b>                      | <b>182</b> |
| 7.1      | Introduction . . . . .                                                                | 182        |
| 7.2      | Output Effects . . . . .                                                              | 186        |
| 7.2.1    | Output, Market Structure and Coordinated Environmental Taxes                          | 186        |
| 7.2.2    | Output, Market Structure and Harmonized Environmental Taxes                           | 191        |
| 7.3      | Trade Effects, Market Structure and Size Asymmetries . . . . .                        | 196        |
| 7.3.1    | Coordinated Environmental Taxes, Trade and Market Structure                           | 197        |
| 7.3.2    | Harmonized Environmental Taxes, Trade Effects and Market Structure . . . . .          | 201        |
| 7.4      | Welfare, Market Structure and Size Asymmetries . . . . .                              | 204        |
| 7.4.1    | Welfare Effects when Environmental Taxes are Coordinated . . . . .                    | 204        |
| 7.4.2    | Welfare Effects when Environmental Taxes are Harmonized . . . . .                     | 211        |
| 7.5      | Conclusion . . . . .                                                                  | 217        |
| <b>8</b> | <b>Summary and Conclusion</b>                                                         | <b>218</b> |
| 8.1      | Introduction . . . . .                                                                | 218        |
| 8.2      | Findings . . . . .                                                                    | 220        |
| 8.3      | Research Significance and Policy Recommendations . . . . .                            | 223        |
| 8.4      | Limitations . . . . .                                                                 | 223        |
| 8.5      | Future Research . . . . .                                                             | 224        |
|          | <b>References</b>                                                                     | <b>225</b> |

# List of Tables

|      |                                                                     |     |
|------|---------------------------------------------------------------------|-----|
| 3.1  | Standard Functional Forms . . . . .                                 | 45  |
| 3.2  | Flexible Functional Forms . . . . .                                 | 47  |
| 3.3  | A Simple Social Accounting Matrix (SAM) . . . . .                   | 59  |
| 3.4  | Extended Model Parameters . . . . .                                 | 64  |
| 3.5  | Key Model Parameters . . . . .                                      | 65  |
| 4.1  | Asymmetric Case Baseline Second Best Environmental Taxes . . . . .  | 88  |
| 4.2  | Description of Shocks . . . . .                                     | 90  |
| 4.3  | Counter-factual Experiments . . . . .                               | 91  |
| 4.4  | Output Effects under the Fixed Wage Closure (% Change) . . . . .    | 94  |
| 4.5  | Output Effects under the Flexible Wage Closure (% Change) . . . . . | 103 |
| 4.6  | Pollution Effects under the Fixed Wage Closure: No FTA . . . . .    | 111 |
| 4.7  | Pollution Effects under the Fixed Wage Closure: FTA . . . . .       | 111 |
| 4.8  | Pollution Effects under Flexible Wages: No FTA . . . . .            | 111 |
| 4.9  | Pollution Effects under Flexible Wages: FTA . . . . .               | 111 |
| 4.10 | Model Variables . . . . .                                           | 112 |
| 4.11 | Model Parameters . . . . .                                          | 113 |
| 5.1  | Output Effects under the Fixed Wage Closure: ASY_IC (% Change) .    | 132 |
| 5.2  | Output Changes under Flexible Wage No FTA Closure- ASY_IC (%)       | 143 |
| 5.3  | Pollution Changes under Fixed Wage No FTA Closure- ASY_IC (%) .     | 154 |
| 5.4  | Pollution Changes under Fixed Wage FTA Closure- ASY_IC (%) . . .    | 154 |
| 5.5  | Pollution Changes under Flexible Wage No FTA Closure- ASY_IC (%)    | 154 |
| 5.6  | Pollution Changes under Flexible Wage FTA Closure- ASY_IC (%) .     | 154 |

|     |                                                                                    |     |
|-----|------------------------------------------------------------------------------------|-----|
| 6.1 | Sectoral Shares by Region . . . . .                                                | 159 |
| 6.2 | Symmetric Case Baseline Second Best Environmental Taxes (\$) . . .                 | 160 |
| 6.3 | Output Effects under the Fixed Wage Closure: SY_IC (% Change) . .                  | 162 |
| 6.4 | Output Effects under the Flexible Wage Closure: SY_IC (% Change)                   | 172 |
| 6.5 | Pollution Changes under Fixed Wage No FTA Closure- SY_IC (%) . .                   | 181 |
| 6.6 | Pollution Changes under Fixed Wage FTA Closure- SY_IC (%) . . . .                  | 181 |
| 6.7 | Pollution Changes under Flexible Wage No FTA Closure- SY_IC (%)                    | 181 |
| 6.8 | Pollution Changes under Flexible Wage FTA Closure- SY_IC (%) . .                   | 181 |
| 7.1 | Output and Coordinated E-Taxes under Fixed Closure (% Change) .                    | 187 |
| 7.2 | Output and Coordinated E-Taxes under Flexible Wage Closure (%<br>Change) . . . . . | 189 |
| 7.3 | Output and Harmonized E-Taxes under Fixed Closure (% Change) .                     | 193 |
| 7.4 | Output and Harmonized E-Taxes under Flexible Closure (% Change)                    | 194 |

# List of Figures

|     |                                                                           |     |
|-----|---------------------------------------------------------------------------|-----|
| 3.1 | Classification of CGE Models . . . . .                                    | 41  |
| 3.2 | Tablo Code for Air Emissions . . . . .                                    | 53  |
| 3.3 | Tablo Code for Second Best Optimal Environmental Tax . . . . .            | 54  |
| 3.4 | Tablo Code for the Polluting Intermediate Input Nest . . . . .            | 56  |
| 3.5 | Tablo Code for Disutility Augmented Regional Household Preferences        | 57  |
| 4.1 | Production Nesting . . . . .                                              | 75  |
| 4.2 | CET Transformation of Domestic Supply and Exports . . . . .               | 79  |
| 4.3 | Welfare Effects under the Fixed Wage No FTA Closure . . . . .             | 99  |
| 4.4 | Welfare Effects under Fixed Wage FTA Closure . . . . .                    | 101 |
| 4.5 | Welfare Effects under Flexible Wage No FTA Closure . . . . .              | 106 |
| 4.6 | Welfare Effects under Flexible Wage No FTA Closure . . . . .              | 107 |
| 5.1 | Demand Decomposition . . . . .                                            | 125 |
| 5.2 | Markup Changes under Fixed Wage Closure - ASY_IC (%) . . . . .            | 136 |
| 5.3 | Welfare Effects under Fixed wage no FTA Closure - ASY_IC . . . . .        | 140 |
| 5.4 | Welfare Effects under Fixed wage FTA Closure - ASY_IC (% Change)          | 141 |
| 5.5 | Markup Changes under Flexible Wage Closure - ASY_IC (%) . . . . .         | 148 |
| 5.6 | Welfare Effects under Flexible Wage No FTA Closure - ASY_IC . . . . .     | 149 |
| 5.7 | Welfare Effects under Flexible Wage FTA Closure - ASY_IC . . . . .        | 150 |
| 6.1 | Markup Changes under Fixed Wage Closure - SY_IC (%) . . . . .             | 165 |
| 6.2 | Welfare Effects under Fixed wage No FTA Closure - SY_IC (% Change)        | 169 |
| 6.3 | Welfare Effects under Fixed wage FTA Closure - SY_IC (% Change) . . . . . | 170 |
| 6.4 | Markup Changes under Flexible Wage Closure - SY_IC (%) . . . . .          | 175 |

|     |                                                                       |     |
|-----|-----------------------------------------------------------------------|-----|
| 6.5 | Welfare Effects under Flexible Wage No FTA Closure - SY_IC (% Change) | 177 |
| 6.6 | Welfare Effects under Flexible Wage FTA Closure - SY_IC (% Change)    | 177 |
| 7.1 | Welfare Effects of Coordinated Taxes under the Fixed Wage Closure     | 205 |
| 7.2 | Welfare Effects of Coordinated Taxes under the Flexible Wage Closure  | 208 |
| 7.3 | Welfare Effects of Harmonized Taxes under the Fixed Wage Closure      | 212 |
| 7.4 | Welfare Effects of Harmonized Taxes under the Flexible Wage Closure   | 215 |

# Chapter 1

## Introduction

*“if they are to succeed, treaties must  
strategically manipulate incentives  
states have to exploit the environment.”*

Scott Barrett

### 1.1 Background and Motivation

The ongoing discussion about international environmental policy cooperation identifies free-rider incentives, sovereignty considerations, uneven costs of implementation and cost uncertainties as key factors that hinder cooperation. Stability in international cooperation requires an incentive structure that favors cooperation over free riding, without hindering national sovereignty. An incentive structure favours cooperation when losses from non-compliance exceed losses from policy compliance. Theoretically, direct monetary transfers cushion regulatory costs, tipping the scale in favour of compliance. Notwithstanding, monetary transfers tend to be impractical because they involve the use taxpayer resources to “pay” other countries to reduce pollution. For this reason, indirect approaches that exploit pre-existing interdependencies between countries are increasingly gaining attention. Collectively known as “issue linkage”, these approaches centre on the notion that the need to maintain key areas of cooperation is likely to infuse agreements with internal and external stability. Two ingredients necessary for cooperation to be self-sustaining.

The need to maintain pre-existing relationships is particularly true for international trade. Trade is not only central to the functioning of any economy, it is also a key driver of economic growth. The literature suggests that under the right conditions, trade-linked policy cooperation can potentially infuse the stability required for sustainable international

environmental policy cooperation. Studies find that under the right conditions, positive trade concessions have the same effects as direct monetary transfers (Turunen-Red and Woodland, 2004). Others highlight the possibility of environmental policy “paying for itself” through free trade (Beghin, Roland-Holst and Mensbrugghe, 2002).<sup>1</sup> Despite the importance and promise of trade linked regulatory policy cooperation, current insights are rudimentary and derive mainly from theoretical analysis. In its current state, the literature fails to address how the regulatory approach, market structure, the nature of trade ties and labour market characteristics affect linked regulatory policy outcomes.

This thesis builds on the trade linkage literature by demonstrating how positive trade concessions, within the framework of free trade, affect collective regulatory policy outcomes. Further, it illustrates the importance of market structure, size asymmetries and labour market characteristics in determining the outcomes of linked regulatory policy. To this end, this thesis quantifies and compares effects of joint corrective taxes on polluting intermediate inputs. In particular, I use Computable General Equilibrium (CGE) analysis to simulate the effects of coordinated and harmonized taxes on output, trade, and welfare. First, to understand how free trade affects collective environmental policy, I draw distinction between regulatory effects under no free trade and free trade assumptions. Further, to illustrate how market structure affects regulatory outcomes, I contrast policy effects under perfect versus imperfect competition. Finally, to demonstrate how the relative size of trading partners influences regulatory policy outcomes, I compare policy effects under asymmetric and symmetric trade ties.

An evolving body of literature maintains that under certain conditions, trade concessions (negative or positive) can restructure incentives in favor of compliance (Barrett, 2003; Turunen-Red and Woodland, 2004; Eichner and Pethig, 2013). However, despite the growing importance of “trade-linkage”, the bulk of the literature is theoretical and has not

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<sup>1</sup>Barrett (1997) considers the effect negative trade concessions on environmental policy participation. He finds that beyond a minimum number of signatories, credible threats of negative concessions can increase policy compliance. Likewise, Eichner and Pethig (2013) explain that when competition characterized by Stackelberg leadership, introduction of free trade significantly increases the size of a stable agreement. Burguet and Sempere (2003) contend that when regions are symmetric, there are welfare gains from combining environmental taxes with free trade.

been subject to empirical rigor. While insightful, theoretical analysis of complex environmental policy interactions is wrought with ambiguities because it is not always possible to determine the exact signs of policy effects. Further, most of the conclusions derive from partial equilibrium analysis. For rudimentary insights, partial equilibrium is a useful tool. However, environmental policy and trade interactions have economy-wide implications, and analysis that fails to incorporate indirect and induced effects offers misleading conclusions. As Conrad (2002) posits, environmental policies affect both product and factor markets, and consequently result in higher costs than predicated by partial equilibrium models.

Even when policies are crafted within the context of trade links, uncertainty regarding the costs and benefits of cooperative policy actions can reinforce non-compliance incentives. To date, analysis of the effects of environmental policy is inconclusive. First, scholars do not agree on the effects of environmental policy on trade. One strand of literature (Tobey, 1990; van Beers and van der Berg, 1997) maintains that trade flows are not responsive to regulatory policy. Others like Ederington and Minier (2003) find that the opposite is true when regulatory policy is endogenous. Further, other seminal studies demonstrate that regulatory stringency has negligible costs in terms of foregone output because abatement accounts for a small fraction of production costs (Jaffe, Peterson, Portney and Starvins, 1995). Fears of competitiveness losses are quite prevalent; however, competitiveness issues are yet to be adequately addressed in the empirical literature. Similarly, no empirical studies exist that adequately address the regulatory approach issues. I am yet to find a study that compares the effects of coordinated and harmonized policies. Studies tend to address these issues separately, whereas effective policy design requires the understanding of the relative implications of the two regulatory approaches.

Although observed trade flows indicate that international markets exhibit imperfectly competitive characteristics, most trade predictions derive from standard models. A meaningful treatment of the effects of regulatory policy is one that includes market structure considerations. The literature shows that under imperfect competition, the effects of regulatory action tend to be magnified (Duval and Hamilton, 2004; Ronson, 2006). Nevertheless, imperfect competition introduces added complexity to the analysis because while market

power in domestic markets reduces consumer welfare, market power in international markets is a source of welfare gains. In international markets, welfare gains derive from increased product variety and substantial economic rents. The preservation of these rents highlights the possibility of the strategic use of regulatory policy. For this reason, some degree of cooperation is recommended to circumvent the strategic use of environmental policy.

Studies show that policy cooperation is potentially welfare improving when strategic motives exist, initial costs of compliance are high or production is characterized by increasing returns to scale (Kox and van der Tak, 1996). Cooperation takes many forms; harmonization and coordination of regulatory instruments represent two examples. Harmonization of policy instruments entails, for instance, the application of uniform taxes across countries. Conversely, coordination involves specifying regulatory instruments like taxes and giving countries the discretion to set their rates/level.

Harmonization of regulatory policies has been suggested to prevent the strategic use of environmental policy and to preserve the competitive landscape of international markets. Proponents of harmonization like Behrens, Hamilton, Ottaviano and Thisse (2007) assert that the uneven application of environmental policy has competitiveness implications. Further, it tends to cultivate incentives for the strategic use of environmental policy. These added incentives make sustainable cooperation difficult. According to recent literature (Turunen-Red and Woodland, 2004; Keen, Lahiri and Raimondos-Moller (2002), under certain conditions, harmonization can be Pareto improving. However, the distribution of regulatory burden of policy harmonization differs across countries. The question is whether free trade would narrow these distributional differences. In fact, when trading regions are asymmetric, and commodity markets are imperfectly competitive, theoretical predictions show welfare gains usually accrue to the smaller region (Cheikbossian, 2010; Behrens et al., 2007). Further, Duval and Hamilton (2004) show that when asymmetries derive from market size, harmonization has superior welfare effects. Similarly, in the case of symmetric trading regions, policy harmonization is likely to benefit at least one region (Keen et al., 2002). Notwithstanding, welfare implications of harmonized policies under imperfect competition requires a deeper analysis.

In contrast, proponents of coordinated policies contend that while policy harmonization is cost effective, it tends to be inefficient. From an efficiency perspective, coordinated policies may be desirable because they depend on country-specific factors. When country-specific issues like employment are considered, coordinated policies can be optimal from a domestic and an international point of view (Hoel, 1997). Studies show that labor market considerations are important determinants of regulatory choices. Hoel (1997) explains that when wages are determined through bargaining, coordinated policies may yield superior outcomes. However, he also notes that coordination is unnecessary under conditions of full employment or real wage unemployment.

In addition to incentives, the choice of regulatory instrument can undermine collective regulatory efforts. This is because some instruments have high administrative requirements, while others do not fully internalize the environmental externality. In the case of environmental taxes, taxes targeting emissions have been extensively studied. Emission taxes have significant administrative requirements and do not directly incorporate unobservable non-point source emissions. The latter are significant contributors to pollution. Targeting inputs that cause emissions can achieve the same objectives, with wider coverage and lower institutional requirements.

Moreover, evidence suggests that a significant proportion of production-generated pollution derives from a small set of intermediate inputs (Dessus, Roland-Holst and Mensbrughe, 2002; Poterba and Rothenberg, 1995). Poterba and Rothenberg (1995) observe that the bulk of environmental taxes are in actual sense, taxes on intermediate goods. Despite these observations, studies on input-based emissions are mainly limited to primary input use. I am unaware of any study that quantifies or compares the effects of coordinating and harmonizing corrective taxes on polluting intermediate goods. As a regulatory target, intermediate inputs are important because they account for 46-52 percent of production requirements and 56 percent of global trade flows.<sup>2 3</sup> Therefore, policies increasing the user costs of polluting intermediate input can potentially alter incentives through their effect on

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<sup>2</sup>46 percent Canada and 48 percent the EU, Statistics Canada

<sup>3</sup>The OECD, 2013

optimizing firm behavior.

## 1.2 Objectives

In this research, I examine whether trade concessions in the form of free trade result in positive regulatory outcomes. In particular, I consider how free trade affects the outcomes of coordinated and harmonized corrective taxes on polluting intermediate inputs. Additionally, this work demonstrates how market structure, labor market considerations and country asymmetries influence responses to collective regulatory actions.

The objectives are fourfold: First, to offer an empirical perspective on trade linked environmental policy. Second, to address the research gap on pollution generated from intermediate input use. Further, to demonstrate the relevance of market structure and country asymmetries in determining the outcome of policy cooperation. Finally, to examine the importance of labor market considerations in understanding international environmental policy design. The latter objective is particularly important because unemployment issues feature prominently in policy decisions.

## 1.3 Methodological Approach

To meet these objectives, I draw from various strands of literature. First, the specification of optimal tax is based on the double dividend literature. Second, the modeling approach is based on Computable General Equilibrium (CGE) modeling. The CGE approach is employed in this research because it allows for the incorporation of complex interactions between environmental policy, market structure and trade. Further, the net results incorporate feedback effects. Finally, the policy shocks are motivated by strategic environmental policy literature.

I use an augmented three-region, ten-sector, and four primary input CGE model to

simulate the effects of coordinated and harmonized corrective taxes on polluting intermediate inputs. I begin by considering regulatory policy between two asymmetric regions, Canada and the EU, under the assumptions of perfect competition and Constant Returns to Scale (CRTS). I simulate the effects of regulatory shocks under free trade and no free trade assumptions and under real wage unemployment and full employment. In the chapter that follows, I relax the assumption of perfect competition by modelling policy effects when under the assumptions of imperfect competition, Increasing Returns to Scale (IRTS) and endogenous market structure. I then relax the assumption of asymmetric regions by simulating policy effects between two large symmetric regions, NAFTA and the EU.

## 1.4 Research Contribution

In carrying out this research, I extend the issue linkage literature by quantifying the effects of free trade on regulatory policy outcomes. By doing this, I will offer an empirical perspective on the theoretical conclusions that trade concessions (positive or negative) can potentially provide the self-enforcement link needed for stable and sustainable environmental policy cooperation. An empirical treatment is important because the current literature on trade linked regulatory policy is mainly theoretical.

By quantifying and comparing effects of harmonized and coordinated environmental taxes, I demonstrate the costs and benefits of the two regulatory approaches. Further, the literature on policy harmonization is mainly theoretical and does not adequately examine the effects of environmental tax harmonization in the context of imperfect competition. I extend the literature by examining the empirical implications of policy harmonization and coordination under both perfect and imperfectly competitive market assumptions.

In addition, I demonstrate how market structure, the relative size of trading partners and labor market considerations influence policy responses. Market structure considerations are important because the observed trend in international markets is indicative of imperfect competition. Further, examination of regulatory policy that ignores market structure

considerations underestimates the effects of regulatory policy because it ignores an important source of feedback, the induced effects through changes in market structure. The distinction between involuntary unemployment and full employment is necessary because employment considerations are key motivators of regulatory action. Finally, because the debate on strategic incentives is mainly theoretical, I examine the predictions of this body of literature empirically by simulating the effects of deviations of optimal taxes.

From a methodological perspective, I extend the Global Trade Analysis Project (GTAP) model by incorporating emissions generated from intermediate use. In addition, I include second best optimal environmental levies on polluting intermediates adjusted to account for labor market inefficiencies. Further, the nesting structure is augmented to include a nest describing substitution possibilities among polluting intermediates. The polluting intermediate input nest allows for isolation of direct impacts of regulatory policy on individual intermediates. Finally, I extend the regional utility specification to account for disutility from pollution.

## **1.5 Results and Findings**

Results in this research demonstrate that free trade does not always improve regulatory outcomes. For Canada in particular, combining regulatory policy with free trade can potentially result in significant regulatory costs. In contrast, when paired with a smaller region (Canada), the EU unambiguously gains from combining coordinated environmental taxes on polluting intermediate inputs with free trade. However, when paired with a region of similar size, NAFTA, free trade can have perverse effects on regulatory responses. Perverse effects occur in both regions. Essentially, a region can lose from free trade if it results in the reallocation of resources from sections with substantial scale economies such that it reduces real output.

Moreover, the findings of this research suggest that environmental policy design has to include market structure, region size and labor market considerations for it to be effective.

In general, when trading regions are asymmetric, policies that combine taxes on polluting intermediates with free trade are less costly in terms of output foregone and welfare. Similarly, collective policy between regions of similar size is less costly. In the case of asymmetric trading regions, when markets are competitive, real wage rigidities can have adverse implications for harmonized taxes for the EU, especially in the absence of free trade. Similarly, when markets are imperfectly competitive, real wage rigidities can result in significant losses for the region if coordinated taxes are not combined with a corresponding removal of border taxes. Finally, industrial organization considerations are important in determining of collective policy outcomes and incentives.

## 1.6 Structure of Thesis

This thesis has eight chapters. The second chapter presents a review of the literature with two objectives. First, to provide theoretical backing for the key modeling issues. Second, to highlight competing theories on the issues addressed in this body of work. Chapter 3 gives a nontechnical overview of Computable General Equilibrium Modeling (CGE) and discusses the model data. Chapter 4 outlines the simulation effects of harmonization and coordination of corrective taxes on polluting intermediates between two asymmetric regions competing in competitive markets. Chapter 5 extends the analysis in Chapter 4 by relaxing the assumptions of perfect competition and Constant Returns to Scale (CRTS). The analysis in chapter 6 considers policy outcomes when symmetric regions interact under imperfect competition. Chapter 7 considers how market structure and the nature of trade ties (asymmetric or symmetric) influences collective policy outcomes. In particular, it compares the three cases to ascertain the role that market structure and asymmetries play in determining policy outcomes. The eighth chapter summarizes and concludes the thesis and discusses limitations and research extensions.

# Chapter 2

## Literature Review

*“making the marginal private cost equal  
marginal social cost does not provide  
Aladdin’s lamp for the applied welfare  
theorist.”*

Buchanan

### 2.1 Introduction

This chapter serves two purposes; first, it provides background literature to this thesis and, second, offers a theoretical justification for the assumptions employed in the analysis. The research draws from four sub-fields of applied microeconomics; public economics, international trade, industrial organization and Computable General Equilibrium (CGE) modeling. The literature has seven sections: Section 2.2 explores the environmental policy cooperation and the trade linkage debate. Section 2.3 provides background and justification to the tax policy modeling and discusses strategic incentives and approaches to regulatory policy cooperation. Section 2.4 considers the literature on environmental policy cooperation and harmonization. Sections 2.5 and 2.6 discuss the effects of environmental taxes under perfect and imperfect competition respectively. The discussion concludes with a synthesis of the literature to establish motivate for this thesis and outline the research questions in section 2.7.

## 2.2 Environmental Policy Cooperation and Trade Linkage

Issue-linked international environmental policy cooperation is an evolving subfield that leans heavily on theoretical analysis, possibly due to the complexity of the issues involved. Issue linkage is the explicit recognition that linking environmental agreements to pre-existing interdependencies among nations may be a means to foster stability in international policy cooperation. Linking agreements to trade ties has the potential to foster stability because trade is important and concessions can proxy side payments. Moreover, regardless of the coverage of an externality, environmental externalities have a trade dimension. Among the studies to date, there is no consensus about the ability of pre-existing trade ties to encourage international policy compliance.

One of the earliest studies to incorporate environmental policy cooperation into a trade model is that of Barrett (1997).<sup>1</sup> He asserts that pollution and its reduction are invariably linked to trade. Pollution reduction has trade implications because unilateral attempts to reduce emissions can result in the loss of comparative advantage. Further, non-participation limits the effectiveness of collective regulatory actions because it results in pollution leakage. Barrett notes that when trade instruments are available, changes in comparative advantage can be circumvented by border adjustments. If credible, the threat of border adjustments can potentially reduce incentives to free ride. Barret contends that beyond a minimum number of signatories, an increase in the number of policy participating countries raises potential losses from credible threats of negative trade concessions.<sup>2</sup> However, he notes that when the number of participants is below the minimum threshold, cooperation is unprofitable. Barrett's work shows that there is a minimum threshold beyond which stable and sustainable cooperation is possible. Further, his work is an important starting point because it explains how credible trade threats can change the strategy space in favor of compliance

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<sup>1</sup>Copeland (2000) also considers trade-linked environmental policy. He shows that when trade is liberalized, efficiency can be enhanced if free trade is combined with a binding agreement on environmental policy

<sup>2</sup>This occurs to the point where the threat of losses exceeds incentives to free-ride.

provided a minimum number of participants. Notwithstanding, if trade occurs within the confines of a Free Trade Agreement (FTA), the use of trade sanctions is not pragmatic.

Ederington provides an economic justification for trade linked regulatory policy. First, he explains that except for when a small country has local pollution and operates under perfect competition, there is a case for negotiating over environmental policy.<sup>3</sup> Essentially, there is scope for regulatory collective regulatory policy even when pollution is local because (a) unilateral action causes spillover costs to trading partners and (b) time inconsistency issues. Ederington contends that there is scope for linking regulatory policy to international trade cooperation when emissions are local, transboundary and when it is difficult to monitor domestic policy. He explains that when setting domestic policy, countries will tend to ignore the spillover costs of lower regulatory standard. By potentially reducing domestic prices, a lax regulatory stance creates additional costs for its trading partners. Therefore, from a global perspective, such a policy would increase global inefficiencies. Further, Ederington draws contrast between two types of linked agreements: negotiation linkage and enforcement linkage.<sup>4</sup> The former suggests making membership of one agreement conditional on the participation in another.<sup>5</sup> This type of linked policy accommodates Barrett's (1997) argument of negative trade concessions. Importantly, he argues that linked regulatory policy is weakly optimal under both perfect and imperfect competition market structures.

Turunen-Red and Woodland (2004) present a case for linking environmental policy to multilateral trade agreements. As a departure from Barrett (1997), they consider positive trade concessions as distributional tools. They contend that by suitably altering trade tariffs, the redistribution of gains from multilateral cooperation can have a mutually beneficial. Their model includes production generated pollution and abatement technology. Turunen-Red and Woodland compare efficiency gains from direct lump sum transfers to gains from

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<sup>3</sup>Ederington highlights the possibility of gains when environmental policy are complements or substitutes. Complements in the sense that the value of one agreement rises as the other is reached. This is implicitly implied in Kenney (1994). Substitutes when the value of one agreement falls when cooperation on the other is reached

<sup>4</sup>The enforcement linkage concerns enforcing compliance within an existing agreement; enforcement by a supranational organization.

<sup>5</sup>Similarly, Conconi and Perroni (2002) distinguish between issue linkage and issue tie-ins. They explain that issue is endogenous while issue tie-ins make cooperation in one issue conditional on cooperation in another.

positive trade concessions. They find that if Terms of Trade (TOT) are sensitive to policy changes, direct transfers, and positive trade concessions have the same effect. Further, if all countries have the same environmental evaluation, harmonization of regulatory instruments can be welfare improving.<sup>6</sup> Turunen-Red and Woodland's findings lend support Barrett's (1997) introducing trade policy considerations in environmental cooperation enlarge the strategy space for international treaty formulation.

An empirical assessment of incentives to cooperate under Research and Development (R&D) linked environmental cooperation is done by Kemfert (2004). She argues that linking R&D to collective regulatory policy compliance can reduce incentives to free ride. R&D linked participation induces positive efficiency, competitiveness, and trade effects. For this reason, net costs of collective environmental policy to society are lower with R&D.<sup>7</sup> Nevertheless, Kemfert, explains that if positive spillover effects accrue to non-signatories, free-rider incentives can be reinforced. In addition, she finds that an increase in the number of cooperating parties increases the incentive to cooperate; a result similar to Barrett(1997). Kemfert also shows that issue linkage across asymmetric countries reduces differences in regulatory costs. However, the author stresses that cooperation does not guarantee stability and neither do trade barriers constitute a significant deterrent of free riding.

Regulatory cost asymmetries are an additional factor that hampers policy cooperation, especially when cooperation occurs between large and small countries. Limao (2005) highlights the growing importance of trade linkage in fostering cooperation in a wide range of issues (p.176). Similar to Barrett (1997), he examines the effectiveness of threats of trade sanctions. However, he restricts his analysis to emission taxes. Limao (2005) notes that cooperative agreements are subject to incentive constraints that balance gains from noncompliance against losses from retaliation (p.177). He identifies (a) regulatory costs, (b) strength of lobbyists and (c) the complementarity and substitutability between trade and environmental policy as incentive constraints. When two policies enter a government's

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<sup>6</sup>They however stress that it is not necessary for preferences or measurement of damages to be the same across countries.

<sup>7</sup>For a high emission country, regulatory costs can be high and in the absence of cost cushioning incentives, this would deter participation.

objective function as complements, cooperation in both policies is more profitable than cooperation on single issues if costs of regulation are sufficiently high and lobbyists exert limited influence.

To investigate the importance of trade in international policy cooperation in the presence of price leadership, Eichner and Pethig (2013) extend Barrett (1997) and others by developing a Stackelberg model with followers acting non-cooperatively. By comparing policy outcomes under autarky and trade, they observe that when competition is Stackelberg, free trade significantly increases the size of a stable agreement (p.46).<sup>8</sup> Also, trade increases welfare and reduces pollution damages. However, they find that the level of emissions is the same under free trade and autarky. This implies that although free trade potentially increases cooperation, its negligible effects on emissions can render it ineffective. To the best of my knowledge, Eichner and Pethig is first attempt to model pollution trade interactions in the presence of industry leadership. While insightful, their analysis ignores abatement activities, consumption and labor interactions, and government revenue.

The preceding literature shows that there is scope for trade policy to foster stable regulatory cooperation. For instance, when TOT are sensitive to regulatory policy, trade concessions are equivalent to monetary transfers (Turunen-Red and Woodland, 2004). The redistributive effect of trade concessions cushion regulatory costs, while the threat of losing these concessions makes free-riding less attractive. Furthermore, there are potential welfare gains to linking regulatory policy to international trade cooperation. Notwithstanding, the discussion is mainly theoretical.

## 2.3 Environmental Tax Design

While policy makers have a wide array of regulatory instruments, if the objective is to change free riding incentives, increasing the user cost of pollution is likely to achieve the objective. Policies that influence the user cost of pollution through incentive-based instru-

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<sup>8</sup>Depending on parameter values, the coalition can be much larger than stated in earlier studies.

ments are designed to influence behavior through the signaling of the price system (Starvins, 2001). There are two categories of market-based instruments; transferable discharge permits and environmental taxes. According to Starvins, in theory, if properly designed and implemented, environmental taxes can result in the reduction of emissions to a desirable level at the least possible cost to society. In addition to the ease administration, two principles guide instrument choice, (a) targeting and (b) efficiency/optimality.<sup>9</sup>

### 2.3.1 Optimal Environmental Tax Design

Theory dictates that there is an optimal level of taxation that minimizes (maximizes) welfare losses (gains). In his seminal article, Pigou (1920) establishes that in the absence of other distortions, optimal internalization of an externality requires that the level of taxation equals Marginal External Damages (MED). Taxes set according to this principle are called first best or Pigouvian taxes. Given that Pigouvian taxes internalize externalities without creating further distortions, they are efficiency improving environmental taxes. Pigou's formulation is central to environmental policy design because it serves as a benchmark for evaluating stringency of regulatory policy. However, the Pigou framework is rudimentary, and it ignores the existence of other distortions. In reality, tax-induced distortions and imperfectly competitive markets are commonplace. More importantly, damages from externalities tend to be unobservable, making MED difficult to measure. In the presence of these distortions, an optimal outcome can only be achieved by using second best instruments.<sup>10</sup>

A series of papers by Bovenberg and van der Ploeg (1996) and Bovenberg and Goulder (1996) show that when an economy is distorted by pre-existing taxes, the use of an environmental tax based on the Pigouvian principle is costly to society. This is because the tax exacerbates labor market distortions by reducing the real wage and labor supply, thus reducing government revenue. Because welfare losses from reduced labor supply and

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<sup>9</sup>An effective tax targets the source of the externality. An efficient tax maximizes gain at the least possible cost to society.

<sup>10</sup>The term second best arises because the additional constraint prevents the attainment of the first best optimum. Formalized by Lipsey and Lancaster (1956-7), the theory of second best dictates that when a constraint that prevents the first best attainment is introduced into a general equilibrium setting, an optimal equilibrium can only be achieved by departing from first-best conditions (p.11).

government revenues potentially exceed gains from regulation, they recommend adjusting the Pigouvian tax to account for labor market inefficiencies. The latter is measured by the Marginal Cost of Public Funds (MCPF), which also proxies as the shadow price of government consumption.<sup>11</sup> Bovenberg and Goulder estimate the MCPF in the US to range between 1.24 and 1.29. They derive an optimal tax for polluting intermediates by adjusting the MED to account for tax-induced distortions via the MCPF. The authors suggest that, when labor supply elasticity is greater than zero, the optimal second-best tax should be lower than the Pigouvian rate. Bovenberg and van der Ploeg's, and Bovenberg and Goulder's tax specification is more reflective of society. In considering pre-existing labor market distortions, the authors provide a pragmatic approach to regulatory tax design. However, they ignore about labor heterogeneity and wage determination considerations.

Parry and Oates (2000) also support the position that regulatory policy applied in the presence of pre-existing distortions can result in welfare losses in excess of gains from pollution reduction. However, their specification of second best optimal tax in the presence of labor market distortions differs from Bovenberg and Goulder (1996a). In particular, Parry and Oates specify the second best optimal tax as the sum of three effects: (i) the welfare effect associated with damage reduction, (ii) the revenue recycling effect explaining the use of added revenue to reduce distortionary labor taxes and the interaction effect, which incorporates the effects of the tax on the labor market. The first two are unambiguously positive. However, when the third effect dominates, regulatory action reduces welfare. In essence, the presence of pre-existing distortions can potentially invalidate benefits of pollution reduction.

As an extension to Bovenberg and Goulder (1996a), Ballard and Goddeeris (2004) examine the role of preferences in determining the second best optimal tax. Unlike Bovenberg and Goulder, they consider pollution from the consumption of a dirty good. When preferences are homothetic and non-separable, their results support prediction of a second-best optimal tax that is lower than the Pigouvian rate. However, when the assumption

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<sup>11</sup>This is measured as the ratio of Marginal Utility of Public Revenue to Utility of Private Income. A value greater than unity indicates that labour is overtaxed and government funds are more costly than private income.

of homotheticity is relaxed, Ballard and Goddeeris recommend an optimal tax in excess of the Pigouvian rate, provided the dirty good is more complementary to leisure. Also with non-homothetic preferences, the labor market response to a tax on the polluting commodity depends on the elasticity of expenditure on the dirty commodity. Here their analysis differs from Bovernberg and Goulder because the latter ignores demand side considerations and instead considers labor supply elasticity as the important determinants of labor market responses. The discussion of the second-best taxation is not limited to labor market imperfections.

Katsoulacos and Xepapadeas (1995) consider optimal taxation when the extra distortion is due to market power. They include abatement and damage costs in the firm's cost function. In addition, they compare second best policy determination under assumptions of entry and no entry. They posit that the second best optimal tax is a function of marginal external damages, imperfect competition, and the entry effect. Further, for certain parameter values, the presence of entry implies that the optimal rate exceeds the Pigouvian rate. The opposite is true when the number of firms is fixed. Accordingly, a lump sum transfer that increases market concentration can be welfare improving.

Similarly, Requate (2005) posits that the positive of the second best tax relative to the Pigouvian rate depends on cost asymmetries and the curvature of the industry demand curve. In particular, the optimal second best environmental tax falls below the Pigouvian rate if costs are sufficiently similar. In contrast, the second best optimal tax exceeds the Pigouvian rate when cost differences are significant, and the demand curve is sufficiently convex.<sup>12</sup> Requate's analysis highlights demand characteristics and the industrial cost structure as important considerations in determining second best regulatory taxes. Like Requate, van Long and Soubeyran (2005) consider costs in their determination of second best taxes. As a departure from other studies, they consider firm-specific corrective taxes. They show that when two firms emit the same emissions per unit output, cost differences could be the basis for differential application of taxes. However, when markets are competitive, the

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<sup>12</sup>For a linear demand curve, the second best optimal equals the first best. If the demand curve is strictly concave, the optimal rate exceeds the Pigouvian rate. The opposite is true for a strictly convex demand curve.

optimal tax should be the same for all firms regardless of the cost differences. More importantly, van Long and Soubeyran (2005) define the empirically relevant range of the MCPF as  $1 \leq MCPF \leq 2$ .

### 2.3.2 Strategic Motives and Environmental Tax Design

The likelihood of strategic motives influencing regulatory choices is an important factor in choosing an approach to collective regulatory policy. The tendency to use environmental policy as a strategic tool is particularly strong when markets are imperfectly competitive. In imperfectly competitive markets, the existence of substantial rents creates incentives to manipulate trade flows in favour of domestic markets. The possibility of rent shifting motivates regulators to set below optimal regulatory targets to increase market share to capture oligopolistic rents. In this case, governments deliberately worsen of Terms of Trade (TOT) through domestic policy. Alternatively, policy makers may be motivated to shift the regulatory burden to foreign consumers or improve Terms of Trade (TOT) by setting above optimal regulatory targets (Kennedy, 1994; Markusen, 1975). Recently van Long and Soubeyran (2005), identify the “pro-concentration motive” as an alternative reason for the strategic use of environmental policy. The pro-concentration motive is based on the premise that regulatory stringency increases efficiency in international markets by driving out inefficiency firms. Finally, employment considerations also influence the size the regulatory instrument in relation to the first best optimal.

The view that when markets are imperfectly competitive, governments may be motivated to use domestic policy to subsidize export flows has its theoretical foundations in Brander and Spencer (1985). Using a Cournot model of two regions competing within a third, they demonstrate that a fall in export prices resulting from subsidization shifts profits to domestic firms. Further, they find this to have positive welfare effects. Building on this framework Barrett (1994) considers the strategic use of environmental policy. Like Brander and Spencer, part of Barrett’s analysis centers on quantity competition. He, however considers the use of environmental standards and demonstrates the importance of the internal

market in influencing strategic motives. Specifically, he shows that when the internal market is monopolistic, incentives may favor a relaxed policy stance. In contrast, if the internal market is oligopolistic, the government is less likely to under internalize the externality. When competition is quantity based, Barrett (1994) demonstrates that regulators are likely to over internalize externalities regardless of the characteristics of the internal market.

Similarly, Kennedy (1994) uses a Cournot model to illustrate the interaction between emission taxes, strategic incentives and market share. According to Kennedy, the presence of imperfect competition can give rise to strategic interaction among governments and as a consequence the inefficient distortion of pollution taxes. He further argues that the possibility of capturing oligopolistic rents can motivate governments to set below optimal taxes.<sup>13</sup> If instead, government objectives favor Terms of Trade (TOT) improvements or shifting the regulatory burden to foreign consumers, the motivation would be to set above optimal taxes. In addition, Kennedy (1994) finds emissions to be determinants of relative market shares. Unlike Barrett (1994), he demonstrates how the extent of transboundary pollution influences strategic distortions and the associated welfare changes. More importantly, when markets are imperfect, the benefits of free trade cannot be realized in the absence of an environmental agreement (p.61).

Ulph (2001) lends support to the contention that the presence of market power gives rise to strategic motives. His analysis differs from earlier studies like Barrett (1994) and Kennedy because he focuses on the choice of policy instrument as a determinant of strategic motives. In addition, Ulph considers both government and firm-level strategic behavior. He illustrates how R&D activities can be manipulated through emission taxes and standards. According to the author, strategic incentives are lower when standards are used as regulatory instruments. Further, incentives for government to act strategically are reduced when firms act strategically. In contrast, when governments act strategically, firms are more inclined to act strategically. However, he stresses that strategic incentives are weak. Two important insights emerge from this analysis; first, understanding strategic incentive requires the need to understand how governments and firms interact. Second, emission taxes are more likely

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<sup>13</sup>Rent is defined as the sum of profits from exports and export tax revenue

to fuel strategic behavior.

Another strand of the literature (van Long and Soubeyran, 2005) discusses the interaction between environmental policy and market integration in oligopolistic markets. Specifically, it highlights the possibility of pro-concentration motives and distortionary motives in the design of regulatory policy. van Long and Soubeyran (2005) contend that when firms are asymmetric, environmental taxes should be firm specific. Firm-specific regulations could be designed to increase industrial concentration. This is because a concentrated market can potentially enhance productive efficiency. In particular, with firm specific taxes, high-cost polluters will be subject to a higher tax rate.

The possibility of strategic actions in international markets fuels competitiveness concerns. The preceding discussion presents arguments in favour of setting non-optimal regulatory targets. Most of the conclusions derive from theoretical models. The empirical understanding of the actual outcomes of non-optimal regulatory actions is an important and important factor in designing cooperative regulatory interventions.

## **2.4 Approaches to Cooperation: Harmonization vs. Coordination**

### **2.4.1 Policy Coordination**

There are two positions of environmental policy coordination. One strand posits that coordination of regulatory policies is only efficient when pollution is transboundary. However, there are a number of studies argue that policy coordination is necessary even when pollution is strictly local. Kox and van der Tak (1996) note that there is scope for efficiency gains even when emissions are strictly local. They highlight the possibility of welfare gains from cooperation when (a) strategic motives exist, (b) initial compliance costs are high and (c) substantial scale economies exist. The authors explain that when a country is small, and exports are a major source of revenue and positive externalities, unilateral regulatory costs

can result in significant welfare losses for both domestic and global markets.<sup>14</sup> Additionally, when trade is liberalized under imperfect competition, the possibility of strategic use of environmental policy strengthens the case for policy coordination. Similarly, Kennedy (1994) asserts that the benefits of trade liberalization cannot be fully realized without cooperation on regulatory policy.<sup>15</sup>

Like Kox and van der Tak (1996), Hoel (1997) examines environmental policy coordination when markets are imperfectly competitive. Nevertheless, Hoel(1997) arrives at a significantly different conclusion; regulatory coordination is unnecessary when emissions are strictly local. He explores whether policy coordination is welfare improving under different labour market assumptions. Hoel finds that when labour markets are characterized by real wage unemployment or fully employment, regulatory policy coordination is not welfare improving. If instead, wages are determined through the processes of bargaining, policy coordination can enhance welfare. Hoel's (1997) analysis assumes away international trade, a key consideration in setting regulatory targets.

Hoel includes international trade and transboundary pollution in his 2005 study. In this case, Hoel (2005) finds that lack of policy coordination results in triple inefficiencies. The inefficiencies arise from (a) the high level of emissions, (b) uneven distribution of transboundary emissions and (c) international trade. Hoel (2005) contends that in the absence of trade policy instruments, strategic incentives result in uneven application of environmental taxes across sector. Inefficiencies arise because the policy is not cost effective. For a given level of total emissions, coordinated/harmonized policies result in lower abatement costs. If instead, trade policy tools are available, tariffs can be used to influence domestic and foreign markets through border adjustments. He also finds policy coordination to be welfare improving when trade policy tools are quantity restrictions.

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<sup>14</sup>This is because of a fall revenues and a decline of positive external spillovers associated with exports. Such a country could improve welfare outcomes by subsidizing exports or entering into a cooperative agreement. The former would put an additional strain on export revenues. While the latter would be welfare-enhancing if the country receives transfers to cushion the regulatory burden.

<sup>15</sup>Copeland (2000) offers a similar view. He posits that in the absence of trade policy instruments the possibility of the strategic use of environmental policy instruments results in inefficiencies. Free trade can result in an efficient outcome if countries enter into a cooperative agreement on environmental policy

According to Cheikbossian (2010) when commodity markets are imperfectly competitive coordination of regulatory taxes between two countries can result in one setting a tax rate that is too low in an attempt to shift rents to domestic markets. Considering policy interaction between a small and large region and assuming pollution is not purely trans-boundary, Cheikbossian demonstrates that when country-specific coordinated taxes are set above a predetermined minimum, coordinated taxes are likely to benefit the smaller region.

The preceding papers are all theoretical studies of policy coordination under imperfect competition. Moreover, they do not quantify net gains from coordinated policies. Neither do they compare gains from coordinated policies under the free trade and no free trade assumptions. While Hoel (1997) offers some insights into regulatory policy coordination under varying wage determination scenarios, his analysis occurs in the absence of trade. For this reason, his predictions have limited practicality because trade is an important feature in any economy.

### 2.4.2 Policy Harmonization

The case for harmonization of emission taxes is often made to deter the strategic use of environmental policy instruments to manipulate trade.<sup>16</sup> The tax harmonization literature considers harmonization based on origin (Origin Principle) or destination (Destination Principle).<sup>17</sup> In this thesis, I adopt the Destination Principle (DP). Keen, Lahiri and Raimondos-Moller (2002) consider the implications of harmonizing commodity taxes when markets are imperfectly competitive. When markets are imperfectly competitive, the authors suggest that a weighted harmonized tax based on the countries' initial positive taxes is potentially Pareto improving regardless of the tax principle (p.1560).<sup>18</sup> Further, harmonization is welfare improving when taxes are applied in the destination market, provided a compensatory mechanism exists. In addition, harmonization is beneficial to the home country if the initial

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<sup>16</sup>While there is growing consensus on the need to harmonize regulatory regimes, questions of national sovereignty and harmonization principles garner some opposition.

<sup>17</sup>Taxes are paid in the region where the commodity is consumed. This implies that taxes are levied only on imports and domestically consumed domestic production.

<sup>18</sup>The choice of tax principle has no bearing on welfare implications under perfectly competitive commodity markets.

tax is positive.

Behrens, Hamilton, Ottaviano and Thisse (2007) consider tax harmonization, size asymmetries and market structure.<sup>19</sup> The authors contend that tax harmonization encourages efficiency when taxes across countries differ. In addition, under standard competitive assumptions, harmonization of taxes can prevent countries from using domestic policy to manipulate domestic and foreign activity. Nevertheless, when markets are perfectly competitive, and harmonizing countries are asymmetric, the smaller region always loses regardless of the level of taxation. If instead, markets are imperfectly competitive and regions are symmetric, harmonization will make at least one region better off. Under the assumption of endogenous market structure, the government that with a more stringent policy stance loses capital to the lower tax region. Further, Behrens et al. find that setting a minimum harmonized tax results in a skewed distribution of firms because it induces an outflow of capital from the smaller region. In contrast, an upper bound tax results in a more even distribution of firms between countries. Their analysis shows that the relative size of regulated countries and the market structure affect welfare outcomes of harmonization. What is not apparent however is the size of initial taxes of the regulating regions.

According to Vlassis (2013), harmonization of pollution taxes in both small and large open economies can result in welfare gains provided production prices remain constant. In addition, if pollution is purely local and regulatory revenues are used to finance abatement activities, harmonization is welfare improving. Moreover, in the presence of trans-boundary pollution moving from an arbitrary tax structure towards harmonization is potentially welfare-improving. He however notes that when market structure and TOT are considered, the results can be ambiguous. The author's analysis centers on the assumption of zero consumption prices and taxes. However, by making this assumption, he ignores important demand policy interactions.

According to Duval and Hamilton (2004), production costs, industry size and the distribution of the global consumer base are important considerations for the design of en-

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<sup>19</sup>They consider perfect competition and monopolistic competition with endogenous market structure.

environmental taxes. They consider tax harmonization between asymmetric regions. Unlike the preceding studies, Hamilton and Duval explicitly define the sources of asymmetries. They examine asymmetries on the basis of (a) the distribution of the global consumer base, (b) costs and (c) like Kennedy (1994), extent of transboundary pollution. Their results suggest that when asymmetries between countries derive from cost differences, harmonization is sub-optimal. Harmonization is welfare improving if the source of asymmetries is the distribution of the consumer base.

In a similar study, Cheikbossian (2010) discusses harmonization between asymmetric regions and conditions under which harmonization would yield welfare gains. He explains that when the asymmetric effect is strong, and emissions are not purely transboundary, the smaller region gains from policy harmonization at the expense of the larger. His result differs from Behrens et al. (2007) because he considers environmental taxes while the latter base their analysis on capital taxes. Nevertheless, both studies make no mention of the initial tax or trade structure. Moreover, they ignore cost and demand considerations.

In contrast, Vlassis (2013) finds harmonization of pollution taxes in both small and large open economies to be welfare improving provided production prices remain constant. Unlike Hamilton and Duval (2004), he makes the case for harmonization when emissions are purely local. According to Vlassis when pollution is purely local and regulatory revenues are used to finance abatement activities, harmonization is welfare improving. Moreover, when pollution is trans-boundary, moving from an arbitrary tax structure towards harmonization is potentially welfare-improving. Notwithstanding, when market structure and TOT are considered, the results can be ambiguous. Vlassis's analysis centers on the assumption of zero consumption prices and taxes. In making this assumption, he ignores important demand policy interactions.

The preceding discussion highlights the important reasons for policy coordination and harmonization. First, coordination can be beneficial even when pollution is transboundary. In addition, it can reduce the triple inefficiencies arising from transboundary pollution in open markets. The uneven application of taxes can potentially nurture strategic incentives.

Harmonization, on the other hand, can potentially circumvent strategic incentives. The discussion also shows condition under which either regulatory approach is welfare improving. Nevertheless, the literature is theoretical and most of the insights derive from imperfectly competitive markets. This is understandable given that strategic issues arise mainly from imperfect competition in international markets. According to Keen et al. (2002), the interaction between tax harmonization in general and imperfect competition is yet to be sufficiently explored. Importantly, none of the studies consider coordination or harmonization of intermediate inputs.

## 2.5 Environmental Taxes under Perfect Competition

Krutilla (1991) uses theoretical partial equilibrium analysis to analyze the effects of corrective consumption and production taxes on a large country competing in perfectly competitive international markets. He considers the case where emissions are purely local and are controlled by unilateral action. Krutilla highlights the importance of monopoly rents in determining the net effects of regulatory policy. He finds that a policy combining a corrective production tax with free trade reduces the volume of exports and trade when the regulating country is a net exporter of the regulated good. The net exporting region, however, experiences welfare gains from larger monopoly rents resulting from higher prices. The opposite is true if the country is a net importer of the regulated good.<sup>20</sup> Krutilla also notes that for a productive tax to be welfare improving, a large net exporting country would have to set a second best tax above the Pigouvian rate. In contrast, an optimal tax on consumption would have to be set below the first best optimal.

As a departure from Krutilla (1991), van Beers and van den Bergh (2000) consider the effects of regulatory taxes on three types of trade flows: total bilateral flows, total bilateral flows of pollution-intensive energy products and total bilateral flows of non-energy pollution intensive commodities.<sup>21</sup> They compare their findings to earlier empirical studies

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<sup>20</sup>If instead, the tax is on consumption, the net exporter's exports rise, but welfare falls.

<sup>21</sup>mining, chemicals, pulp and paper, steel and non-ferrous metals.

by Tobey (1990) and van Beers and van den Bergh (1997) who find that trade in pollution intensive products to be invariant to regulatory stringency.<sup>22</sup> Van Beers and van den Bergh's (2000) results point to the existence of a significant relationship between aggregate trade flows and regulatory stringency. In terms of sectoral impacts, they show that at a more disaggregated level, flows of pollution intensive commodities are not very responsive to regulatory stringency. The latter result confirms earlier findings by Tobey. These results are based on standard partial equilibrium framework. This limits the practical application of their findings because they ignore feedback effects of regulatory stringency, and market imperfections.

Harris, Konya and Matyas (2002) also build on van Beers and van den Bergh (1997). They analyze the effects of environmental taxes applied to commodities sold in perfectly competitive markets. Unlike earlier studies, they consider six types of regulatory stringency and consider fixed effects. They find regulatory stringency to have no significant real effects on trade flows. However, in the presence of fixed effects, their results suggest a significant negative relationship between regulatory stringency and trade flows. While their analysis offers a different perspective to van Beers and van den Bergh, it suffers the same limitation; it ignores important indirect effects of regulatory policy. Moreover, their measures of policy stringency are limited to the demand and supply of energy. Comparing their findings to cost- based measures could offer important insights.

Cole and Elliot (2003) extend Tobey (1990) by evaluating industry specific effects of environmental policy on trade. Like Tobey, they consider effects of regulatory policy within Heckscher-Ohlin framework, but go further by extending their analysis to new trade models. In addition, they use a larger data set, two measures of regulatory stringency and control for industry-specific effects and endogeneity. Moreover, as a departure from Harris et al. (2002) and van Beers and van den Bergh (2000), they consider trade flows of pollution-intensive goods. The authors find when markets are perfectly competitive, exogenously determined environmental policy has minor effects on the flow of pollution-intensive goods. Likewise,

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<sup>22</sup>van Beers and van den Bergh (1997) finds a variation in the behaviour of exports and imports. According to the authors regulatory stringency reduces imports in general. In contrast, it has no significant effect on dirty commodity exports, but reduces the exports of clean commodities

endogenously determined policy has negligible effects on aggregate trade flows. Once the assumption of perfect competition is relaxed, Cole and Elliot demonstrate that regulatory policy is a significant determinant of intra-industry trade (p.1170). Given that imperfect competition is an observable characteristic of international commodity markets, their results imply that in practice, the link between regulatory policy and trade is significant. Notwithstanding, their partial treatment ignores indirect and induced effects associated with change in market structure.

Treating environmental taxes as endogenously determined, Ederington and Minier (2003) lend support to the theoretical proposition that the regulatory policy influences trade flows. They argue that previous studies found no significant relationship between trade flows and environmental taxes because regulatory because they assumed exogenously determined taxes. Unlike previous studies, they use compliance costs as a proxy for regulatory stringency. Ederington and Minier derive their conclusions by comparing effects of endogenously and exogenously determined policy stringency. When the taxes are exogenous, their results support Tobey (1990), van Beers and van den Bergh (1997, 2000), Harris et al. (2002) and Cole and Elliot (2003). Nevertheless, when lobbying and political activities influence regulatory decisions, trade effects are significant. The preceding studies reveal that when the analysis of regulatory stringency is based on partial equilibrium models, empirical results are inconclusive. Further, predictions are sensitive to whether the regulatory instrument is endogenous or exogenous. In fact, the preceding insights derive from analysis that ignores important feedback effects of regulatory policy.

Gallegos (2005) considers regulatory effects in the context of a theoretical general equilibrium model of trade and environmental policy. Specifically, he analyzes the effects of corrective taxes on polluting intermediates under perfect competition. He considers three regulatory instruments (i) a pollution tax, (ii) a commodity tax and (iii) a tax on polluting intermediates. Using the Pigouvian tax as a reference point, Gallegos demonstrates that the welfare is maximized at the first-best tax rate. Further, when the pollution tax is set at the first best optimal, free trade maximizes welfare. If, however, the pollution tax on the polluting intermediate is the only policy instrument, raising the tax is welfare improving.

The theoretical analysis also shows that when the economy is distorted by both pollution and trade taxes, there are two policy instruments and the pollution-intensive sector is highly protected, welfare can be improved by a setting an above optimal corrective tax or moving towards free trade. In other words, in the absence of free trade, welfare can be improved by a more stringent policy stance.

Roland-Holst and Bussolo (2002) is among the few empirical studies on the international of free trade with regulatory taxes on intermediate inputs. They use a dynamic Applied General Equilibrium (AGE) of trade and environmental to simulate the effects of corrective taxes on intermediate inputs and free trade. In particular, the authors consider the European Community (EC)-Morocco free trade agreement. To model emissions, the authors use emission coefficients estimated by Dessus, Roland-Holst and Mensbrugghe (2002).<sup>23</sup> When they simulate and compare the effects of emission taxes under no free trade and free trade assumptions, Roland-Holst and Bussolo's arrive at three main conclusions. First, environmental policy in the absence of free trade has negative growth effects. Second, in the absence of regulatory policy, free trade reduces welfare through its effects on the level and intensity of pollution. Third, there are potential welfare improvements from combining corrective taxes with trade liberalization.

Roland-Holst and Bussolo present the case of joint regulation between two asymmetric regions under perfect competition. In addition, it charts regulatory effects over a period of 10 years. Their analysis also suggests strong interaction effects between pollutants.<sup>24</sup> Combining trade with regulatory effects can result in a significant reduction in pollution without the negative growth consequences. Notwithstanding, Roland-Holst and Bussolo consider unilateral regulatory action by Morocco. They fail to consider how a cooperative approach with the EU would affect Morocco's growth over time.

In the same series, El Obeid, Mensbrugghe and Dessus (2002) apply the model used by Bussolo et al. (2002), to the Vietnam/USA FTA. Here asymmetries between the two

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<sup>23</sup>Dessus et al.'s estimates reveal that a small set of intermediate inputs (less than ten) account for 90 percent of the variation in production generated emissions.

<sup>24</sup>regulating one pollutant effectively reduces the emissions of other pollutants.

regions derive from both population and income. They consider regulatory effects on the small country, Vietnam. As in the case of Bussolo et al., they find a free trade cum corrective tax policy to be welfare improving. Unlike, the previous analysis, however, El Obeid et al. use a more disaggregated data set. This enables them to identify and isolate policy sensitive sectors and sectoral feedback effects. For instance, they find the mining sector to be particularly sensitive to regulatory changes. In particular, the mining sector contracts by 20.2, 30.7 and 16.4 percent over three-time periods in response to effluent taxes in the absence of free trade. Similarly, taxes on Volatile Organic Compounds (VOC) increase activity in the mining sector by 34.5 and 64.8 percent (p.216).

In a similar study, Adkins and Garbaccio (2007) model the interaction between trade and environmental policy under assumptions of perfect competition and Constant Returns to Scale (CRTS). They extend the GTAP model to include labor market distortions and emission taxes. The modified model includes 24 productive sectors and 21 regions. Adkins and Garbaccio (2007) find that although emission taxes offset gains from free trade, welfare in all regions increases.

The importance of substitutability and complementarity of capital, labor and polluting inputs in determining regulatory outcomes is highlighted in Fullerton and Heutel (2007). Using theoretical general equilibrium analysis, they examine the effects of emission taxes on output and the returns to labor and capital. They demonstrate that when capital and labor have equal factor intensities and are substitutes, the return for the input substitutable with the regulated good will rise. In contrast, if capital and labor are complements, a pollution tax can reduce the return of the more substitutable input. In essence, the stronger substitute can bear a higher regulatory burden. Moreover, when factor intensities differ, a tax on a dirty input can increase the return to a substitute input if the degree of substitution between inputs exceeds the degree to which consumers substitute between outputs (p.573). Finally, despite the reallocation of resources from the private sector induced by environmental taxes, scope exists for one factor to gain. This analysis is important because it shows how ignoring feedback effects of regulatory policy can yield misleading results. In addition, it highlights the significance of factor interactions in determining regulatory responses. However, the

predictions are theoretical and cover only two sectors.

A more recent study by Babool and Reed (2010) empirically investigates sector specific of regulatory stringency on trade flows. Specifically, they analyze the effects of emission taxes on the competitiveness of the manufacturing industry in the OECD using standard factor endowments analysis with R&D to model trade flows for the period 1987-2003. The authors identify pulp and paper, metals and chemical sectors as pollution intensive. Contrary to earlier predictions, Babool and Reed (2010) find environmental stringency to have significant negative effects on trade flows. However, the results indicate that pulp and paper exports increase with regulatory stringency, partly because this sector is skilled and capital intensive (p. 2322). They also highlight the role of capital and labor intensities in determining regulatory policy outcomes. Notwithstanding, these conclusions derive from a partial equilibrium standard trade model.

## **2.6 Environmental Taxes under Imperfect Competition**

Models based on perfect competition fail to explain observed patterns of global trade. Evidence suggests that the bulk of global trade is intra- industry trade. In addition, global markets tend to be imperfectly competitive and characterized by substantial scale economies. Because of this, the analysis of environmental policy based solely on perfect competition can result in misleading conclusions. Trade theories that account for features of intra-industry trade, imperfect competition, and scale economies are collectively termed “ new trade theories”.<sup>25</sup> The class of models in the new trade category is broad. However, this section considers regulatory policy and quantity based imperfect competition.

Markusen, Morey and Olewiler (1993) use a theoretical general equilibrium model to explore the effects of environmental taxes under imperfect competition with endogenous

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<sup>25</sup>The term “ new trade theories” has been used since the 1980s, a more appropriate term would be “extended trade theories”.

market structure. They assert that that regulatory cost can be substantial if endogenous market structure is assumed away. The authors demonstrate that for certain values of taxes, sizable welfare gains can result from environmental taxes if the combined effect of pollution reduction, higher fiscal revenues, and increased firm-level profits dominate losses in consumer surplus. However, if the tax is too restrictive, the loss in market share and associated oligopolistic profits combined with a loss in consumer surplus can result in a net welfare loss. It is worth noting that their conclusions are dependent on the assumptions of endogenous market structure and non-revenue neutrality. Further, while they note that changes in market share have welfare implications, they ignore scale efficiency effects. When competition is quantity based, regulatory policy can result in induced effects through marginal costs and scale efficiencies without having a significant effect on the market structure.

Similarly, Burguet and Sempere (2003) consider the effects of bilateral reduction in border taxes between symmetric regions competing in imperfect markets. They compare the welfare effects of combining environmental corrective taxes and standards on private consumption with free trade. The authors find welfare effects to be positive when taxes are used as a regulatory instrument, but negative when standards are used provided demand is very elastic or the damage function is steep.

Jug and Mirza (2005) empirically analyze the effects of regulatory action under monopolistic competition using a modified gravity model. They assume incomplete pass through and Spence-Dixit-Stiglitz preferences. Like Ederington and Minier (2003), they consider cost-based regulatory stringency. Contrary to earlier predictions by van Beers and van den Berg (1997) and others, they find trade flows to be sensitive to regulatory stringency. Expressly, they find the elasticity of trade with respect to abatement to be  $-3.54$  (p. 1612). Moreover, to ascertain whether the difference with other studies is due to their data set or structural differences in the theoretical model, they apply their data set to van Beers and van den Berg (1997) and Harris et al. (2002) models. They find results consistent with the two studies. Jug and Mirza, therefore, conclude that the conflicting results are due to model specification. Further, applying the model to US data yields results consistent with Ederington and Minier.

Bohringer, Welsch and Loshel (2001) also consider regulatory policy under imperfect competition but use CGE analysis. They contend that the use of standard trade models presents a partial picture of policy outcomes because, in reality, markets are predominantly imperfect. The presence of imperfect competition is likely to reinforce regulatory policy through its effects on already distorted output and margins. Further, Bohringer et al. maintain that regulatory costs are potentially higher under imperfect competition. They support this proposition by comparing regulatory outcomes under perfect and imperfect competition. According to their results, a \$36/ton carbon tax results in a 0.24 and 0.26 percent contraction in output under perfect and imperfect competition respectively. Bohringer et al. explain that while aggregate effects may be similar, sectoral effects are stronger under the alternative market structure. They emphasize the link between perceived elasticity, economies of scale and output in understanding the effects of policy in imperfect markets. However, welfare losses are higher under imperfect competition because induced efficiency losses dominate efficiency gains from investment. Bohringer et al. conclude that total regulatory burden under imperfect competition depends on the responsiveness of economies of scale to policy.

Conrad (2002) surveys the use of CGE models in environmental policy analysis. He explains the importance of labor market specification in determining the effect of policy on employment, a usually contentious issue in environmental policy formulation. In the context of double dividend analysis, the author compares the effects of a non-uniform and uniform carbon tax of Euro 21/ton of carbon. Results show that output reduction is slightly lower (0.35 percent) when taxes are uniform compared to the alternative (0.36 percent). On average, output effects of either policy in the EU are negligible. On the contrary, Conrad finds the labor dividend and welfare to be lower under the uniform tax scheme. He attributes the fall in welfare to the fall in consumption and leisure associated with the carbon tax. At the country level, Conrad finds labor in countries with an initially high carbon tax to benefit from a lower uniform tax and vice versa. He gives an example of Italy, where the uncoordinated tax is higher than the uniform tax; the gains in employment are lower at 0.23 percent compared to 0.34 percent under the non-uniform scheme.

## 2.7 Summary and Conclusion

The preceding literature lends theoretical support to the contention that trade concessions can potentially foster stable environmental policy cooperation. Turunen-Red and Woodland (2004) show that positive trade concessions yield the same outcomes as direct monetary transfers provided TOT are sensitive of regulatory policy. Offering a different perspective Barrett (1997) shows that beyond a minimum number of signatories, credible threats of negative concessions reduce incentives to free ride. While these and other studies (Pethig and Eichner, 2013) lend credence to the linkage suggestions, conclusions are mainly theoretical. The question of whether free trade improves regulatory outcomes requires deeper empirical investigation.

The literature in this chapter suggests that second best taxes are more representative of real economies. However, the discussion highlights divergent interpretations of what constitutes optimal second best taxation. Further still, there are interesting but contradictory views on strategic motives in tax design. Whether above or below optimal taxes are welfare improving is not clear in the literature. More importantly, studies point to the possibility of strategic motives but do not necessarily test whether the motivations result in positive outcomes. In fact, the vast body of literature is mainly theoretical.

Divergent views on the effects of regulatory stringency on trade flows highlight the need for further investigation, especially using richer and more realistic model specifications. From the studies surveyed, the question of the effects of regulatory policy on trade flows is skewed towards partial equilibrium analysis. As mentioned earlier on, empirical partial analysis for environmental trade interactions leaves out important feedback effects of policy. It is possible that when analyzed within the context of general equilibrium, these questions can result in different or opposite conclusions. Both partial and general equilibrium theoretical models and, on the other hand, suffer from indeterminacy. The indeterminacy is because it is not always possible to establish the net effects of policy changes.

Issues of environmental tax harmonization in the presence of imperfect competition

are yet to be adequately addressed in both theoretical and empirical literature (Keen et al., 2002). Further, to the best of my knowledge no study exists that compares the effects of policy harmonization and coordination in either a perfectly competitive or imperfectly competitive setting. Moreover, apart from Cheikbossian (2010), the literature is silent on the effects of harmonization of taxes on polluting intermediate goods. This is true despite evidence that the bulk of pollution derives from the use of a small set of polluting intermediates (Benarroch and Weder, 2006; Dessus et al., 2002; Poterba and Rothenberg, 1995).

CGE models of trade and the environment are important tools in addressing the regulatory effects of policy. Nevertheless, because the studies surveyed address mainly welfare effects of policy, output and trade effects are not apparent. To date the question of harmonization and coordination of corrective taxes on key polluting intermediates is yet to be addressed within an applied general equilibrium context. Further, while labor market considerations are important determinants of policy decisions, empirical studies addressing outcomes of policy harmonization and coordination under varying labor market assumptions do not exist. Moreover, while a few studies investigate the effects of harmonized policy under asymmetric and symmetric country assumptions, the insights are rudimentary and largely theoretical. This is the case despite the possibility that cooperation between countries of similar size is likely to yield different outcomes compared to cooperation between asymmetric countries. These are important pieces to the trade linkage puzzle. For this reason, this thesis answers the following questions:

1. Does the conclusion that free trade improves environmental policy outcomes hold when empirically tested?
2. Are the purported benefits of combining regulatory policy with free trade sensitive to the underlying market structure?
3. How does the relative size of trading partners affect collective regulatory policy outcomes?
4. Does the regulatory approach matter?

5. Are labor market considerations important determinants of regulatory outcomes?

To answer these broad questions, I consider three cases: (i) trade between asymmetric regions competing in perfectly competitive markets. (ii) Trade between asymmetric regions competitive under imperfect competition and (iii) asymmetric regions competing in imperfectly competitive commodity markets. The first simulates effects of harmonized and coordinated air emission levies under standard neoclassical assumption. Specifically, the model developed is applied to the Canada-EU trade ties. The second case considers the two asymmetric regions when trade is more reflective of reality that is, it incorporates industrial organization considerations. Because of the continuum of imperfectly competitive models, I limit the discussion to quantity based competition with endogenous market structure. In comparing the two cases, I demonstrate how market structure considerations affect regulatory policy outcome. In the third case, the assumption of symmetry is relaxed, the imperfectly competitive model is applied to the NAFTA-EU trade ties. The objective of the third case is to show how the relative size of trading partners influences policy responses.

In the next chapter, I discuss the concept of CGE modeling, paying specific attention to the salient features of the methodology. Further, I explain the data used for this analysis and outline the key model variables.

# Chapter 3

## Research Methodology and Data

*“For a complete and precise solution of partial problems of the economic system, it is inevitable that one must consider the system as a whole.”*

Augustine A. Cournot

### 3.1 Introduction

This chapter discusses the key methodological aspects of this thesis. In particular, it provides a nontechnical overview of Computable General Equilibrium (CGE) modeling and the structure of the model data. The research questions outlined in the previous chapter are addressed by extending the standard GTAP model to include emissions, taxes on polluting intermediates, a welfare measure augmented to reflect changes in pollution and features of industrial organization. The GTAP model is developed and maintained by the Center for Global Trade Analysis at the Purdue University. Its theoretical foundations derive from the Walrasian General Equilibrium, specifically, the Johansen (1960) and Scarth-Shoven-Whalley class of models.<sup>1</sup>

This chapter has seven sections. Section 3.2 provides the background and theory of CGE modeling paying particular attention to its importance, the theoretical foundations and evolution. Section 3.3 discusses the salient features of CGE modeling. These include the process of production nesting, functional forms, the treatment of international trade, macro closure, and welfare determination. Section 3.4 outlines the model extensions. Sections 3.5 and 3.6 explain the model data and implementation respectively. Section 3.7 concludes the

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<sup>1</sup>Scarth (1967) and the subsequent additions by Shoven and Whalley (1972)

chapter with a discussion on the limitations of the methodology.

## 3.2 Background to CGE Modelling

The methodology of Computable General Equilibrium (CGE) modeling has become a standard tool for analyzing complex economic issues that have potential economy wide impacts. General Equilibrium (GE) refers to a set of prices and quantities that equate supply and demand in all markets. The term computable is appended because the models are solved using computation techniques. Specifically, it is a representation of the Walrasian GE as a system of non-linear simultaneous equations solved numerically.<sup>2</sup> CGE models consist of behavioral equations that describe supply and demand side behavior, prices, taxes and institutional constraints. Teixeira and Domingos (2006) describe CGE models as a “powerful tool for representing price-dependent interactions at market level, while at the same time retaining microeconomic consistency” (p.2).

The CGE modeling approach plays an important role in applied research by operationalizing economic theory to explain complex interactions. Bohringer, Rutherford and Wiegard (2004) maintain that CGE modeling incorporates micro-systems analysis of complex economic problems where analytical solutions are either not available or do not provide adequate information. In addition, the strong microeconomic foundations of CGE models, allow for the incorporation of complex detail into the consumer and producer decision-making process. For instance, the nested production technology allows the researcher to incorporate different levels of substitution among inputs and functional forms. Moreover, by linking all sectors of the economy, CGE modeling captures the intricate interactions within the whole system allowing for the identification of policy impacts on individual components. Conrad (2002) posits results from theoretical studies can be ambiguous because it is not always possible to determine the signs of net effects. By quantifying the effects of policy simulations, CGE models enable researchers to overcome this ambivalence in theo-

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<sup>2</sup>It can also be described as a set of equations linked to one another by accounting identities and market equilibrium conditions.

retical results. More importantly, results are rooted in rational behavior of economic agents (p.4).

Of specific importance to the current thesis, the CGE approach is flexible enough to allow the incorporation of externalities and features of industrial organization. Further, for complex problems like regulatory policy and trade, this approach permits the quantifying of direct, indirect and substitutionary effects of regulatory policy. In contrast, partial analysis tends to underestimate costs and benefits of regulation because it ignores sectoral interdependencies and more representative measures of social costs of regulation. Indirect policy effects potentially account for the larger proportion of changes in real variables. Partial equilibrium analysis paints an incomplete picture of policy responses because it ignores these effects. It is possible that once indirect effects are considered, policy effects can be the direct opposite of those predicted by partial analysis. Furthermore, the structure of demand allows for the isolation of domestic and foreign responses at both the aggregate and sectoral level.

Having made the case for CGE modeling, the next subsection describes the theoretical and historical foundations of the methodology used in this research.

### **3.2.1 Theoretical Foundations**

CGE modeling operationalizes the abstract Arrow-Debreu notion of General Equilibrium (GE). In particular, it uses data to offer solutions to supply, demand and institutional interactions that support equilibrium within a closed system.<sup>3</sup> Arrow-Debreu Walrasian GE forms the theoretical basis of this approach. This theory posits that under the assumptions of perfect competition and Constant Returns to Scale (CRTS), optimizing behaviour by consumers and producers results in a set of prices and quantities that equate demand and supply across all markets. The notion of GE implies that an economic system is com-

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<sup>3</sup>Scricciu (2006) describes a CGE model as an analytical deterministic integrated system of non-linear equalities derived from optimizing behavior of rational agents that describes simultaneous linkages between markets, institutions and factor resources, and renders an all markets clearing equilibrium numerical solution.

plete, consisting of inter-dependent components; domestic industries, households, governments and economic, foreign agents. Put simply, “the theory of general equilibrium is the formalization of a simple but fundamental observation that real world markets are inter-dependent (Bergman, 2005 p.1275). This interdependency implies that every perturbation pulses through the whole system. A more concise representation of CGE modeling given by Shoven and Whalley (1984) asserts that CGE modeling converts the abstract notion of Walrasian GE into a pragmatic representation of the economy.

### **3.2.2 Historical Underpinnings**

CGE modeling has evolved into an important subfield and an indispensable tool in dealing with global issues. Its theoretical foundations derive from Leon Walras’ (1874) seminal work titled “Elements of Pure Economics”. In this discourse, Walras presents an elaborate mathematical description of a General Equilibrium. Which he expresses as a system of simultaneous equations representing market equilibrium (Shoven and Whalley, 1984; Piermartini and The, 2003). According to Walras, under certain conditions, non-zero prices will ensure that any market shall be in equilibrium if all other markets are in equilibrium. Essentially, for non-zero prices, aggregate demand equals aggregate supply. Later, in order to distinguish Walras’ proposition from Say’s Law, Lange (1942) calls it “Walras Law.” While Walras Law is an important building block because it establishes the equality between the number of equations and endogenous variables, and aggregate demand and supply, it is considered a necessary but not sufficient condition for the existence of a unique equilibrium.

Later, Arrow and Debreu (1954) and Debreu (1959) formalized Walras Law. Using fixed point theorems, they specified three necessary and sufficient conditions for the existence of a unique equilibrium. First, all firms earn zero economic profits. Second, economic agents operate on their budget constraints. And third, demand equals supply in both factor and commodity markets. In addition, Arrow and Debreu presented a formal elaboration of welfare properties of this equilibrium (Myles, 2001). However, Scarf and Shoven (1984) note that the theoretical breakthroughs of Arrow-Debreu and others did not adequately explain

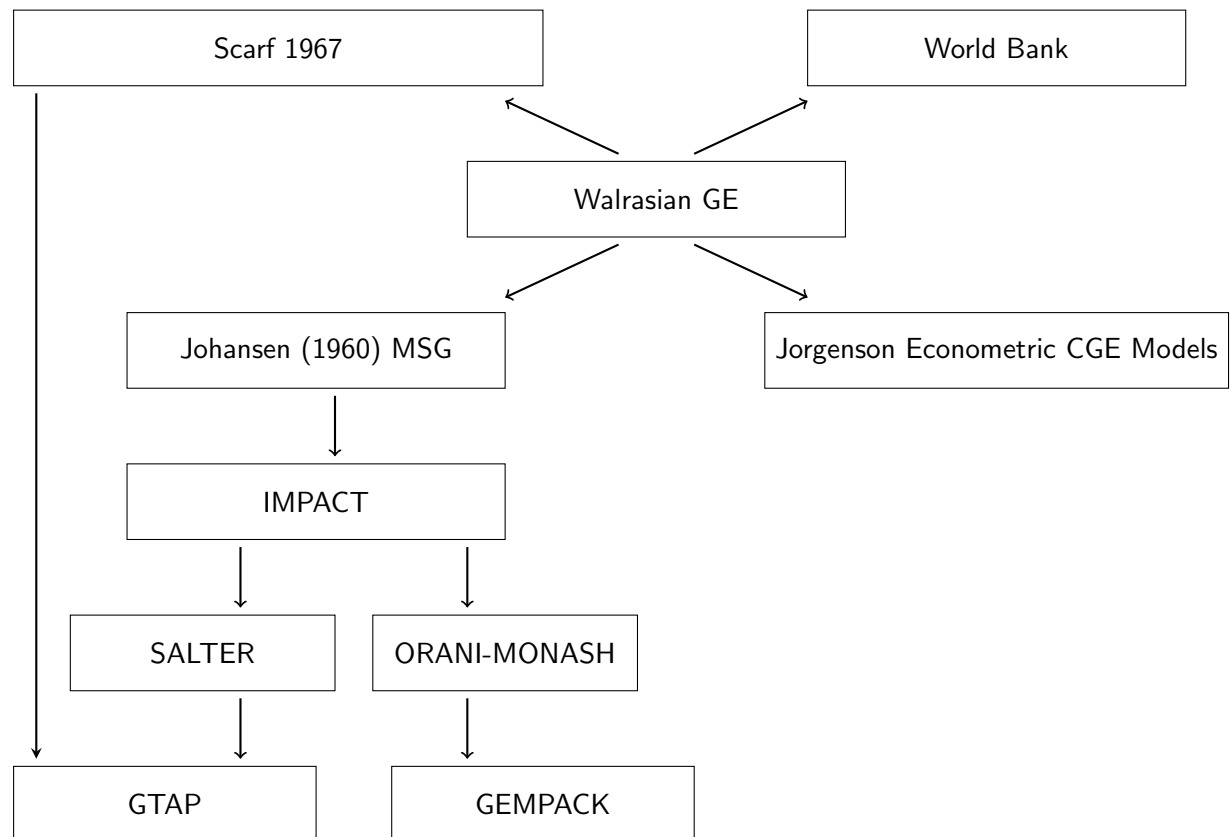
the process of price determination. Further, they did not elaborate on how prices could be used as practical tools in the very types of economic analysis that provided the initial motivation for general equilibrium models. A closely related and important development was the introduction of Input-Output (IO) by Wassily Leontief in 1941. Leontief's contribution formed the basis for the data structure of CGE models called Social Accounting Matrices (SAM). The main differences between the two are that the latter contain institutional detail and endogenous specification of quantities. In addition, his incorporation of environmental analysis into IO analysis in Leontief (1970 ) and Leontief (1973) laid the foundation for environmental augmented SAMs.

During the 1960s, leading GE economists developed and refined theoretical propositions on the existence, uniqueness, optimality and stability of solutions to general equilibrium models (Dixon and Parmenter, 1996, p.6). The transition from the Walrasian GE to computable models is attributed to two main developments. First, the development of the Multi-Sector Growth Model (MSG) by Leif Johansen in 1960. And second, the development of a computer algorithm for the numerical determination of the Walrasian system by Herbert Scarf. These developments evolved into four main classes of CGE models. Expressly, the (i) Johansen (1960), (ii) Scarf (1967), (iii) Jorgenson (1969) and the World Bank (iv) models. Figure 3.1 presents these four categories.

Johansen (1960) is credited as being the first to implement a general equilibrium model numerically. More importantly, he was the first to introduce optimizing behavior into CGE modeling. According to Dixon and Rimmer (2010) by "specifying production and consumption he made a distinction between buyer's prices (that motivate consumption decisions) and seller's prices (that motivate production decisions)". In his doctoral dissertation titled "the Multi-Sector Study of Economic Growth" , he developed a dynamic linear model of the Norwegian economy consisting of 20 sectors and one representative consumer. In this model, he used the Arrow-Debreu notion of equilibrium, but added macroeconomic features. Johansen (1960) was particularly interested in the interaction of real variables and long-term growth. For this reason, his model presented a slight departure from the Walrasian tradition. Bergman (2005) contends owing to this departure, Johansen's work was

an approximation of the Walrasian General Equilibrium.

Figure 3.1: Classification of CGE Models



Later, independent research by Scarf (1967) presented a breakthrough in computational techniques by creating a direct link between theoretical work and computable modeling. In particular, he established an efficient method of solving GE models by developing an algorithm for computable models. Unlike Johansen, Scarf’s work is firmly grounded in the neoclassical Walrasian tradition. Bergman (2005) describes Scarf’s approach as “putting numbers to a GE model”. In extending Scarf’s model, his students Whalley and Shoven proved the existence and designed a computational technique for solving GE models with taxes . Models grounded in the Scarf tradition are called Scarf-Shoven-Whalley class of models. These models are mainly static and focussed on the normative issues of efficiency and welfare.

The World Bank class of models derive mainly from Johansen’s analysis. As a de-

parture, however, their models are non-linear. This class of models has different variants, a common feature is that they are growth based and tailored towards developing country modeling.

The fourth and most recent class of CGE models is rooted in Jorgenson (1984). The Jorgenson class of models rely on econometric techniques to estimate parameters instead of calibration. Jorgenson draws from both Johansen and Scarf. Like Johansen, these models are predominantly dynamic and in the tradition of Scarf; they are firmly rooted in the Walrasian GE (Bergman, 2005). Jorgenson and associates have been credited with introducing econometrically estimated flexible functional forms, environmental parameters, consumer demands and investment into CGE analysis. The data requirements for this approach tend to be high; however, the econometric “approach makes it possible to incorporate behavioral responses in relative prices based on past behavior” (Conrad, 2002).

It is worth mentioning additional contributions of Leif Johansen. According to Dixon and Rimmer (2010), Johansen provided an algorithm for solving applied models. More importantly, his work formed the basis for the ORANI/MONASH model and the General Equilibrium Modeling Package (GEMPACK). The latter is used to implement models in this research. I have particularly elaborated the evolution of Johansen’s techniques in Table 3.1 to show the link between the methodology used here and the Johansen tradition. Johansen is also credited with providing techniques for organizing and understanding simulation results. Further extensions of the model are now standard to most CGE models. For instance, Dixon, Parmenter, Ryland and Sutton (1977) introduce the Armington specification and Leontief’s IO into the model.<sup>4</sup> Further extensions of Johansen’s work include the use of flexible functional forms in demand and supply side modeling, introduction of flexible closures and the introduction of multi-product and multi-industry specification of the supply side. Not only does Johansen’s work form the basis for the software used to simulate policy scenarios in this research. The base model used here is partly rooted in the Johansen techniques.

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<sup>4</sup>Dixon and Rimmer(2010)

Prior to the 1970s, empirical research was predominantly based on econometric techniques. CGE modeling gained momentum in the 1970s due to unexpected changes in the research landscape. First, the oil price shocks were a new development; there was no historical data to base econometric analysis on. The lack of historical data on the movement of price shocks presented new challenges to econometricians, and according to Dixon and Parmenter (1996), rendered econometric analysis unsuitable for the explaining effects of price shocks. Dixon and Parmenter note that attempts at using econometric techniques yielded results that showed that price of oil data had insignificant or zero coefficients. These results implied that oil was not an important determinant of economic activity. Clearly, this approach yielded misleading results and as a consequence, partly stimulated interest in CGE modeling.

Further, owing to the development of efficient computer algorithms and databases, the CGE approach has evolved to accommodate a wide array of issues. Software and databases like GEMPACK, GAMS, and GTAP have overcome the initial obstacles and have made it easy for complex empirical issues to be analyzed on a large scale (Bergman, 2005). The large number of country and global models currently available exemplifies the current importance of the CGE approach. CGE has also become a standard tool for trade and environmental analysis because of its global scope and analytical detail.

### **3.3 The Process of CGE Modeling**

The process of CGE modeling has four stages: (i) specification of equations, (ii) data, (iii) calibration and (iv) model implementation. In standard models, for the specification of equations and the underlying assumptions are neoclassical. Optimizing behavior by economics agents follows the standard process of making decisions subject to constraints. There are however features that are unique to CGE models that I discuss in this section. These include the nested structure of producer and consumer decisions making, the choice of functional forms, specification of international trade, macro-closure, and welfare determination. Further, I explain how model extensions are incorporated.

### **3.3.1 Production and Consumption Nesting**

Producer and consumer decisions are modeled using a multilevel decision-making process called “Nesting.” Nesting is central to CGE analysis because it allows for the accommodation of varying degrees of substitutability and complementarity at different levels of the decision-making process. On the demand side, nesting isolates the substitution possibilities between domestic and foreign goods, between goods from different regions and between different commodities. Production nesting isolates substitution possibilities among inputs. More importantly, nesting makes it possible to identify the impacts of shocks on individual inputs and commodities.

Nesting centres on the assumption that consumer and producer problems are separable and can be solved in stages. Graphically, this process is illustrated by a technology tree, which shows substitution possibilities at each stage. In environmental policy modeling, nesting is an indispensable technique that clarifies producer and consumer responses to policy shocks.

### **3.3.2 Functional Forms**

Functional forms are the basis for the determination of consumer and producer behavior and important determinants of policy outcomes. In essence, the results of policy summations depend largely on the specifications of the underlying behavioral functions. At a theoretical level, the choice of functional form is guided by regularity conditions. For a model to have a numerical solution the functional forms underlying producer and consumer behavior must meet the global regularity conditions. A function is globally regular if it meets the conditions of homogeneity, additivity, symmetry and curvature. These regularity conditions ensure that the functional form is consistent with theory. In addition to the global theoretical restrictions, the choice of functional forms is determined by three factors. (i) the ease of computation, (ii) parametric requirements and (iii) the degree to which predictions reflect observable behavior.

There are three categories of functional forms: standard, semi-flexible and flexible. Standard functional forms have low parametric requirements but are very restrictive. For production behavior, standard forms are adequate in predicting supply sides dynamics. In contrast, standards functional forms have limited ability to predict consumer behavior. Specifically, they fail to capture changes in consumer behavior as income and prices change.

### Standard Functional Forms

The class of standard functional forms consists of the Cobb-Douglas (C-D), Constant Elasticity of Substitution (CES) and the Linear Expenditure System derived from Stone-Geary preferences. Table 3.1 lists the three functional forms.

Table 3.1: Standard Functional Forms

|                                           |                                                          |       |
|-------------------------------------------|----------------------------------------------------------|-------|
| Cob-Douglas (C-D)                         | $U = X_i^\alpha X_j^{1-\alpha}$                          | (3-1) |
| Constant Elasticity of Substitution (CES) | $U = (\alpha X_i^\rho + (1 - \alpha) X_j^\rho)^{1/\rho}$ | (3-2) |
| Linear Expenditure System (LES)           | $U = \prod_{i=1}^n (C_i - \theta_i)^{\gamma_i}$          | (3-3) |

Here  $U$  represents ordinal utility,  $X_1$  and  $X_2$  the demand for commodities 1 and 2 and  $C$ , the vector of consumer goods. Parameters  $\alpha$ ,  $\rho$ ,  $\theta$  and  $\gamma$  share, substitution and consumer demand parameters. Subscripts  $i$  and  $n$  in equation 3.3 refer to commodities.

The Cobb-Douglas function, described by equation 3.1 is used extensively in applied modeling because it has minimal data requirements. Calibration of shares requires only data on demand quantities, prices and income all of which are readily available. Similarly, elasticities are easy to calibrate. However, the CD functional form assumes unitary income and uncompensated own-price elasticities and zero cross prices elasticities. These restrictions imply that expenditure shares remain constant as income changes and that demand for one good is not responsive to changes in prices of other goods. These outcomes are inconsistent with empirical observations. For instance, Yu, Hertel, Preckel and Eales (2002) observe

that Cobb Douglas cannot capture dynamic phenomena such as changing trade patterns and consumption patterns. Issues that are relevant to analyzing effects of environmental regulation. More importantly, under the Armington assumption, Cobb-Douglas preferences result in export volumes that are invariant to world price changes. According to Bhattacharai, Gosh and Whalley (1999), this implies “world price changes have no effect on either domestic consumption or production of the domestically produced good”.

Data requirements for the CES, defined by equation 3.2, are similarly low. Substitution and share parameters are calibrated using relative prices and demands. In most cases, substitution elasticities are available in the model database. Therefore, only share parameters are calibrated. The CES is also less restrictive than the Cobb Douglas because it assumes non-unitary and non zero own price and cross price elasticities respectively. However, it retains the assumption of unitary income elasticities and assumes identical substitutability among all commodities. Further, when expenditure shares are low own price and substitution elasticities are the same.

The Linear Expenditure System (LES) described by equation 3.3 relaxes the unitary income elasticity assumption. This functional form is a variant of the CES function. The main difference is that it assumes the existence of a minimum level of expenditure depicted by  $\theta$  in equation 3.3.<sup>5</sup> Like the CD and CES, it has modest data requirements and is easy to calibrate. Notwithstanding, for expenditure levels less than minimum, utility is zero. Further, it assumes linear Engel curves, rules out expenditure elasticities less than zero, elasticities of demand greater than unity and positive cross price elasticities. The first restriction implies expenditure shares are invariant to income and prices, the second rules out inferior goods, the third elastic demand and fourth, assumes related goods are gross complements( de Boer, 2009).

---

<sup>5</sup>The LES is based on Stone (1954). While commonly used in demand side modeling, it is useful in modeling supply side behavior. The Presence of minimum expenditure Implies Constant Returns to Scale (CRTS). This makes it useful in modeling Increasing Returns to Scale (IRTS)

## Flexible Functional Forms

The functional forms discussed in the preceding paragraphs have very rigid restrictions and lead to results that do not conform to empirical practicality, especially when explaining consumer behavior. An alternative is to use flexible functional forms provided they meet the global regularity conditions.<sup>6</sup> Commonly used flexible forms listed in Table 3.2 include the Indirect Addilog System (IAS), An Implicitly Additive Demand System (AIDADS), Constant Difference Elasticity of Substitution (CDE) and the Translog demand system.

Table 3.2: Flexible Functional Forms

|                                                  |                                                                                                            |       |
|--------------------------------------------------|------------------------------------------------------------------------------------------------------------|-------|
| Indirect Addilog System (IAS)                    | $V(m, p) = \sum_{i=1}^n C_i \frac{\left(\frac{m}{P_i}\right)^{\gamma} - 1}{\gamma_i}$                      | (3-4) |
| An implicitly Additive Demand System (AIDADS)    | $\sum_{i=1}^n \frac{\alpha + \beta e^u}{1 + e^u} \left[ \ln \frac{c_i - \theta_i}{A e^u} \right] \equiv 1$ | (3-5) |
| Cost Difference Elasticity of Substitution (CDE) | $\sum_{i=1}^{10} B_i U^{\gamma \rho} \left( \frac{m}{p} \right)_i^{\rho} \equiv 1$                         | (3-6) |
| Translog                                         | $\ln Y = \alpha + \sum_i \beta_i \ln X_i + \sum_i \sum_j \delta_{i,j} (X_i)(X_j)$                          | (3-7) |

Unlike the standard forms, flexible functions do not maintain the restrictions of homotheticity and separability. However, because they meet global regularity conditions, have computational simplicity and conform to underlying CGE assumptions, they are used extensively in CGE modeling. More importantly, these forms tend to yield results superior to the non-flexible forms.

In equation 3.4 variables  $V$ ,  $p$ ,  $m$  and  $C$  are the indirect utility, price vector, income and the consumption vector.<sup>7</sup> The parameter  $\gamma$  represents the reaction parameter.<sup>8</sup> The variable  $u$  in equation 3.5 is the utility,  $\theta$  the minimum level of consumption, and  $\beta, \alpha$  and  $A$ , unknown parameters (Reimer and Hertel, 2010).<sup>9</sup> Parameters  $B, \gamma$  and  $\rho$  in equation

<sup>6</sup>Failure to satisfy these conditions results in failed numerical solutions.

<sup>7</sup>Consumption is bound by the restrictions  $C_i \geq 0$  and  $\sum_{i=1}^n C_i$ .

<sup>8</sup>Where  $\gamma_i \geq -1$ .

<sup>9</sup>These are bound by the restrictions  $\beta_i \leq 1$ ,  $\sum_{i=1}^n \beta_i, \alpha_i \geq 0$  and  $\sum_i = \sum \beta_i = 1$ .

3.6 are expansion, distribution and substitution parameters.<sup>10</sup> Finally  $Y$  and  $X$  represent expenditure and demand quantity in equation 3.7, and  $\alpha$ ,  $\beta$  and  $\delta$  unknown parameters.<sup>11</sup>

According to de Boer (2009), the IAS is easy to implement, presents a richer description of preferences and has non-linear Engel curves. In addition, when restrictions on responsive parameters ( $\gamma$ ) are properly specified, this function yields results for both inferior and luxury goods. He notes that this functional form is likely to yield plausible welfare and expenditure results.

The AIDADS system defined by equation 3.5 is an extension of the LES.<sup>12</sup> Unlike the LES, marginal budget shares in the AIDADS are non-constant. This specification, therefore, allows for a richer description of Engel curves and realistic consumption pattern. Notwithstanding, as total expenditure rises, the asymptotic income and Allen partial elasticities of substitution approach unity for all goods (Powell, McLaren, Pearson and Rimmer, 2002; Cranfield, Preckel and Hertel, 2010). Also, this form is constrained by limited flexibility in prices (Hertel, 1997). As a result, it does not always yield desirable results.

Equation 3.6 defines the Constant Difference Elasticity of Substitution (CDE) function. Developed by Hanoch (1975), the CDE is a non-homothetic, separable implicit expenditure function. In fact, it is a generalized form of the CES function. It depicts an additive relationship between utility ( $u$ ) and the normalized price  $m/p$ . This functional form has the advantage of being flexible and having low parametric requirements. It is globally well behaved, and can readily be calibrated to own and income price elasticities (Hertel, 1997). In addition, income elasticities are non-unitary and variable; the Engel curve has a curvature. Moreover, it exhibits the advantage of theoretical flexibility, without compromising parametric parsimony (Brocker 2005, p.1). It is also separable, a feature that makes it attractive in pollution modeling. Parameters from the CDE function are globally well behaved and yield a unique range of vector of preferences for given prices and expenditures. Results from

<sup>10</sup>The following restrictions apply:  $B_i \gamma_i > 0$  and  $\sum_{i=1}^n B_i = 1$ ,  $0 < \rho < 1$ .

<sup>11</sup>According to Varian (2002), the following restrictions apply:  $\sum_{i=1}^n \beta_i = 1, \delta_{i,j} = \delta_{j,i}$  and  $\sum_{j=1}^n \delta_{j,i}$

<sup>12</sup>The AIDADS becomes the LES when  $\alpha = \beta$ .

the CDE functions are closer to observed data behavior; Engle curves are non linear.<sup>13</sup> Unlike Cobb Douglas function, in the CDE form the price of utility from private consumption is endogenous; it depends on the level of consumption (McDougall, 2003).

The last function, the Translog, is the most flexible but has large parametric requirements. Developed by Christensen, Jorgensen and Lau (1975), this functional form meets the global regularity conditions of homogeneity, additivity, and symmetry, but fails to satisfy the curvature condition.

### 3.3.3 Treatment of International Trade

Traded goods are modeled using two symmetric Armington assumptions, first, imperfect substitutability between domestic and imported goods and second, imperfect transformability between domestic supply and exports. Based on Armington (1969), foreign and domestic goods in CGE models are differentiated only on the basis of country/region of origin. Substitution possibilities between domestic and foreign goods are described by nested Constant Elasticity of Substitution (CES) and Constant Elasticity of Transformation (CET) functions. The former describes the allocation of domestic demand between domestic and imported commodities, while the latter describes the allocation of output between domestic and export markets.

The nested Armington structure for both pairs of goods is bi-level. At the top level, the CES function describes the allocation between domestic and imported composites; the degree of substitution is determined by the Armington elasticity of substitution. Similarly, the second level nest describes substitution between goods from various regions. In GTAP, regional substitution elasticities are assumed twice the size of Armington elasticities. The nesting structure describing domestic and exports supply mirrors the import/domestic Armington structure. The magnitude of the trade elasticities is also an indicator of the degree of competition on world markets.

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<sup>13</sup>Successive increases in consumption do not result in equi-proportionate changes in expenditure

The Armington specification presents a departure from traditional trade theories based on comparative advantage. Expressly, unlike standard trade models, the Armington specification assumes heterogeneity between domestic and imported commodities. This assumption is important because it accommodates two-way trade in similar goods, an observation consistent with trade data. Similarly, the Armington specification avoids extreme patterns of specialization observed in standard trade models. Nevertheless, the assumption of persistent product differentiation implies that Armington based models are likely to underestimate structural effects of long-term changes in relative prices (Bergman, 2005, p.1291). In reality, however, product differentiation depends on market conditions and time, this implies that patterns of specialization change over time.

### **3.3.4 Macro Closure**

A closure is a balancing constraint that does not necessarily represent market equilibrium. It is the process of defining endogenous and exogenous variables to ensure that the model is square. In essence, a system of equations is square when the number of equations equals the number of endogenous variables. At the micro level, closure involves the satisfaction of commodity and factor market constraints. In contrast, macroeconomic closure pertains to the definition of macroeconomic constraints with respect to three macroeconomic balances. The three macro closure rules are: (i) government balance, (ii) savings /investment balance and (iii) the current account balance.

#### **Government Savings/Expenditure Closure Rule**

The government balance equates its expenditure to revenue. In macro closure, government expenditure can be held constant allowing for adjustment through at least one tax instrument. This implies that government savings feature as a residual component measured by the gap between government revenue and expenditure. Alternatively, adjustment can occur through government expenditure holding taxes (the revenue side) constant.

## **Savings and Investment Closure Rule**

In GTAP, savings and investment are analogous to all goods and services in the model (Hertel, Ianchovichina and McDonald, 1997). Various approaches are used to define the savings investment closure. The model can be savings driven where savings adjust to a fixed level of investment. This closure is standard neoclassical. Alternatively, the model can be investment driven where investment adjusts to a fixed level of savings. The latter is also called the Johansen closure. The third option, which is also neoclassical, allows for the adjustment of both savings and investment. The adjustment is done by introducing a portfolio allocation mechanism through a hypothetical “ global bank”. Essentially, the global bank pools savings from various regions and allocates investment based on divergences in the expected rate of return. The global bank reallocation of investment across regions affects production and trade through its effect on the profile of final demand ” (Hertel and Tsigas, 1997, p. 52).

## **Current Account Closure Rule**

There are two closure options for the current account balance. One can opt to fix the current account and allow adjustments to occur through a flexible real exchange rate. This approach is particularly relevant when savings do not enter the aggregate utility specification. Alternatively, the real exchange rate can be fixed, allowing adjustment to take place through changes in the current account. This closure is suitable for welfare analysis when savings enter the regional utility function .<sup>14</sup>

In most models, it is standard to fix the current account and allow adjustments to take place through the real exchange rate. However, a flexible real exchange rate can potentially dampen the shock transmission. According to Conrad (2002), it is not always desirable to endogenize each economic variable, case in point, the exchange rate. This is because it becomes harder to understand the outcome of a policy simulation due to the

---

<sup>14</sup>Hertel et al. (1997) suggest that fixing the current account is the right approach for welfare analysis if savings do not enter the utility function (p.267).

huge number of potential transmission channels (p.29). In the case of environmental policy, shocks are likely to affect the trade balance, through changes in rates of return to capital and a consequent change in regional investment (Hertel and Tsigas, 1997). A fixed trade balance can potentially mask these changes.

### **Welfare Specification**

Changes in welfare are measured by the Equivalent Variation (EV). EV is the income adjustment that would bring the consumer utility to a level consistent with the post shock utility level. A positive EV represents a welfare improvement; it refers to the income that would be given to consumers to enable them to attain a utility level that would prevail had the shock occurred. Similarly, a negative EV is that downward adjustment in consumer income to bring their utility level to the post policy/shock level. In the model EV given by the equation.

$$EV_r = Y_{(EV)r} - Y_{(O)r} \quad (3-8)$$

Expressly, the regional EV is the difference between the expenditure required to obtain the post shock utility at initial prices ( $Y_{(EV)r}$ ) and the initial regional income  $Y_{(O),r}$ . The measure of utility includes disutility from pollution, therefore changes in EV will reflect in addition to consumption and savings, changes associated with pollution reduction.

## **3.4 Model Extensions**

The model employed in the research is an augmented version of the GTAP model. The model is static. This specification avoids the problem of persistent product differentiation associated with the Armington specification. On the supply side, the standard CES and CET functional forms are used to model production and output allocation decisions. As a departure from the standard GTAP model, the first level cost minimization decisions are constrained by CES as opposed to Leontief technology. Similarly, the CDE specification is

employed to explained private household preferences.

With regard to macro closure, government expenditure is assumed to be endogenous. I make this assumption because government expenditure is a significant source of final demand. Because the models used in this thesis are static, capital accumulation and growth issues associated with changes in government expenditure are not of concern. Similarly, as a departure from the standard applications, I endogenize the current account and fix the real exchange rate. This assumption allows for the analysis of the effects of regulatory policy of net exports. The following subsections discuss the key extensions made to the GTAP model for the purposes of this thesis.

### 3.4.1 Air Emissions

Figure 3.2: Tablo Code for Air Emissions

```
Variable(levels) (all,i,POLF_COMM) (all,r,REG)          EM(i,r)
# Emissions #;
Zerodivide default 1.0;
EQUATION (LINEAR) Emissions

# Emissions from per dirty intermediate in j #
(ALL,i,POLF_COMM) (ALL,r,REG)

EM(i,r) * p_EM(i,r) = SUM(j,PROD_COMM,{1- EFATEC * [(TOTABT(i,j,r) /
QPOLF(i,j,r) / {ECOEF(i) * QPOLF(i,j,r)}^(AEFPAR))] * ECOEF(i) *
QPOLF(i,j,r) * p_QPOLF(i,j,r) + ECOEF(i) * QPOLF(i,j,r) * -EFATEC *
AEFPAR * {[TOTABT(i,j,r)/QPOLF(i,j,r) / (ECOEF(i) *
QPOLF(i,j,r))]^(AEFPAR - 1 )} * {1.0 / [ECOEF(i) * QPOLF(i,j,r)] *
[1.0 / QPOLF(i,j,r) * TOTABT(i,j,r) * p_TOTABT(i,j,r) - TOTABT(i,j,r)
/ ({QPOLF(i,j,r)}^(2 )) * QPOLF(i,j,r) * p_QPOLF(i,j,r)] -
TOTABT(i,j,r) / QPOLF(i,j,r) / [(ECOEF(i)*QPOLF(i,j,r))^(2 )] *
ECOEF(i) * QPOLF(i,j,r) * p_QPOLF(i,j,r)} ) ;
! includes abatement expenditure share (TOTABT/VQM)!
Zerodivide off;
```

I include a general specification of air emissions calculated endogenously. Emissions are modeled following Goulder et al.'s (1998) theoretical specification, which defines emissions as a function of emissions per unit of intermediate input and abatement. The specification of emissions is similar to the Environmental Protection Agency's (EPA) calculation of emissions, which adjusts the total emissions to account for abatement efficiency.

Where EM refers to air emissions, TOTABT- total abatement costs, ECOEF – emissions per unit polluting intermediate and QPOLF, the quantity of polluting input.

### 3.4.2 Environmental Tax Design

Figure 3.3: Tablo Code for Second Best Optimal Environmental Tax

```
Zerodivide (nonzero_by_zero) default 0.7;
Formula & Equation (levels) COORD_EMTAX
    (all,i,POLF_COMM) (all,r,REG)
EMTAXC(i,r) = 0.01*[-MED(i,r)*(1/LAMBDA(r))];
Zerodivide(nonzero_by_zero) off;
```

The regulatory instrument is based on the “the polluter pays” principle. The objective is to influence the behavior of producers by making the polluting intermediate more costly. Moreover, incentives tend to be more sensitive to market-based regulatory instruments. The tax framework is based on the “Targeting Principal” (Sandmo, 2001); taxes on externalities should target the activity that generates the externality. A general interpretation of targeting is the “Additivity Property” first discussed in Sandmo (1975). This property dictates that the presence of an externality affects only the formula for the tax on the externality generating good. Therefore, it does not affect optimal taxes on other goods (Kopczuk, 2003, p. 81). Oates (1995) elaborates that if production of a certain commodity generates emissions causing pollution, then the emissions, not the commodity, should be subject to a tax. However, this implies that non-point source emissions will not be subject to tax. Throughout this thesis, I use the targeting principle loosely to refer to intermediate use as the source.

Where c.EMTAX refers to the percent change in the coordinated environmental tax, LAMBDA the MCPF and MED, the marginal external damage.

The discussion in the previous chapter reveals that in a second-best world the optimal tax can be either above or below the Pigouvian optimal. Various tax specifications identified in the literature suggest augmenting the Pigouvian tax to accommodate labor market inefficiencies, market structure distortions and terms of trade. However, for simplicity the tax

specification used in this thesis only accounts for labor market distortions. The preclusion of market structure distortions does not imply that the specification is flawed; the theory of the second best implies that correcting an existing distortion does not always result in Pareto improvements. Similarly, distorting a distorted system further is not always Pareto worsening.

In this thesis the environmental tax centers on three assumptions. First, emissions are generated by intermediate use. Second, emissions are proportional to intermediate use. Finally, distortions in the labor market are accommodated by multiplying the marginal external damages by the inverse of the Marginal Cost of Public Funds (MCPF). The MCPF is a measure of labor market inefficiency and is greater than one. A value greater than one implies that (a) labor is overtaxed and (b) the pollution levy will be less than the Pigouvian level. The latter is the convention specified by Goulder et al. (1998) and adopted in this research. It is worth mentioning that the empirical literature has found MCPF values that fall below unity. For instance, Hansson and Stuart (1985) find a value as low as 0.67 for Sweden. From an efficiency perspective, a value less than 1 implies labor is under taxed; welfare can be improved by increasing labor taxes or imposing an emission levy greater than the Pigouvian rate.

### **3.4.3 Production Nesting**

To isolate the effects of regulatory policy on individual polluting intermediates, I add a nest describing substitution possibilities between polluting intermediates. In addition, prices are adjusted to account for per unit environmental taxes. The equations below describe the code modification:

Figure 3.4: Tablo Code for the Polluting Intermediate Input Nest

```

Variable(levels) (all,j,PROD_COMM) (all,x,REG)                                coal(j,x)
# Quantity demanded of coal #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    coal(j,x) = QPOLF("COAL",j,x);
Equation COAL_DEMAND # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_coal(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("coal",j,x)-
pf(i,j,x)]);
Variable(levels) (all,j,PROD_COMM) (all,x,REG)                                gas(j,x)
# Quantity demanded of gas #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    gas(j,x) = QPOLF("GAS",j,x);
Equation GAS_DEMAND # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_gas(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("gas",j,x)-pf(i,j,x)]);

Variable (levels) (all,j,PROD_COMM) (all,x,REG)                                pet(j,x)
# Quantity demanded of pet #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    pet(j,x) = QPOLF("PET",j,x);
Equation PET_DEMAND
    # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_pet(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("pet",j,x)-pf(i,j,x)]);

Variable (levels) (all,j,PROD_COMM) (all,x,REG)                                mmm(j,x)
# Quantity demanded of mmm #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    mmm(j,x) = QPOLF("MMM",j,x);
Equation MMM_DEMAND # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_mmm(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("MMM",j,x)-pf(i,j,x)]);

Variable (levels) (all,j,PROD_COMM) (all,x,REG)                                ppw(j,x)
# Quantity demanded of ppw #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    ppw(j,x) = QPOLF("PPW",j,x);
Equation PPW_DEMAND # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_ppw(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("ppw",j,x)-pf(i,j,x)]);

Variable(levels) (all,j,PROD_COMM) (all,x,REG)                                cpr(j,x)
# Quantity demanded of opr #;
Formula (initial) (all,j,PROD_COMM) (all,x,REG)
    cpr(j,x) = QPOLF("CPR",j,x);
Equation CPR_DEMAND # Demand for polluting commodities#
    (all,j,PROD_COMM) (all,x,REG)
    p_cpr(j,x)
        = sum(i,POLF_COMM,qf(i,j,x)-ESUBPL(i)*[p_polfc("CPR",j,x)-pf(i,j,x)]);

```

Where coal, pet, gas, mmm, ppw and cpr represent the polluting intermediate inputs coal, petroleum, gas, minerals and metals, pulp and paper, and chemicals respectively. The equations are CES specification of the polluting intermediates. Each equation describes percentage changes prefixed by p-, where p\_polfc, pf and qf represent the relative price of the polluting intermediates, pf, the composite price of intermediate inputs and qf, the composite intermediate input. Finally, ESUBPL is the elasticity of substitution between

polluting intermediates.

### 3.4.4 Regional Utility with Disutility from Pollution

To account for the effects of pollution on consumption, I modify the regional utility function to account for disutility from pollution. This specification centers on the separability of the per-capita Cobb-Douglas per capital utility functions. The equations below describe augmented regional utility code.

Figure 3.5: Tablo Code for Disutility Augmented Regional Household Preferences

```
Equation UTILITY
# Regional household utility #
(all,r,REG)
u(r) =
au(r) + DPARPRIV(r)*loge(UTILPRIV(r))*dppriv(r) +
DPARGOV(r)*dpgov(r)
+ DPARSAVE(r)*loge(UTILSAVE(r))*dpsave(r)
- DPARDISUP(r)*loge(DISUTILPOL(r))*p_disupol(r)+
[1.0/UTILELAS(r)]
*[y(r)-pop(r) - p(r)];
```

Where  $au$  is the shift parameter,  $DPARSAVE$ ,  $DPARGOV$ ,  $DPARPRIV$  and  $DPARDISUP$  are the savings, government expenditure, private household expenditure and disutility distribution parameters, and  $UTILSAVE$ ,  $UTILPRIV$ ,  $UTILGOV$  and  $DISUTILPOL$  per-capita utilities of savings, private consumption, government consumption and disutility of pollution.

### 3.4.5 Competitiveness

Competitiveness takes various meanings in the literature. In this thesis, competitiveness refers to firm-level competitiveness. Essentially, a firm becomes more competitive when it experiences a gain in market share or rise profitability. Therefore, changes in competitiveness are changes in the market share, markups and exports of firms in a sector. Firm-level competitiveness allows for the analysis of strategic policy considerations, and it avoids the

confusion regarding competitiveness at industry level. Expressly, a rise in industrial competitiveness is associated with increased competition and a fall markups.

## **3.5 Data and Calibration**

### **3.5.1 Data**

Data used in CGE modeling is organized in the form of a square matrix called a Social Accounting Matrix (SAM). A SAM shows linkages between Input Output (IO) tables, national accounts, and institutional flows. It provides a link between theory and macroeconomic data. According to Roe, Dinar, Tsar, and Diao (2005), the SAM serves two main purposes, first it is used to identify parameters in the primitives of the underlying economy. Second, it is used to ensure the theoretical model and parameterization is logically consistent. Table 3.3 presents simple SAM where the columns represent expenditures and rows revenues.

The augmented model is calibrated to the Global GTAP volume 6 database compiled by the department of agricultural economics at the Purdue University. GTAP is a multipurpose global database made up of single country SAMs linked by bilateral trade flows. The database consists of Input-Output (IO) data, protection, transport and bilateral trade flows. GTAP presents the global economy as “a system of flows of trade of goods and services, measured as money values, in millions of US dollars” (Dimaranan and McDougall, 2006, p.2.1). The version used for the research consists of 87 regions (countries), 57 sectors and five primary factors.

Table 3.3: A Simple Social Accounting Matrix (SAM)

| Revenues          | Producers                 | Households                    | Government              | Inv. | ROW           | Total Revenue                              |
|-------------------|---------------------------|-------------------------------|-------------------------|------|---------------|--------------------------------------------|
| Producers         |                           | $C$                           | $G$                     | I    | $(X - M)p$    | $C + I + G + (X - M)$                      |
| Households        | $FI$                      |                               | $T$                     |      | $(X - M)h$    | $FI + T$                                   |
| Government        | $\tau Y$                  | $\tau FI$                     |                         |      | $(X - M)g$    | $\tau Y + \tau Y + \tau FI + \tau(X - M)g$ |
| Inv.              |                           | $Sh$                          | $Ig$                    |      |               | $Sg + Sh$                                  |
| ROW               | $(X - M)p$                | $(X - M)h$                    | $(X - M)g$              |      |               | $\sum(X - Mi)$                             |
| Total Expenditure | $\tau Y + tFI + (X - M)g$ | $C + \tau FI + Sh + (X - M)h$ | $G + T + Sg + (X - M)g$ | I    | $\sum(X - M)$ |                                            |

In this thesis, the data is aggregated to three regions, 10 tradable sectors, and 4 primary factors. I have chosen this aggregation scheme to model bilateral environmental taxes and border tax removal and to explore the effects of policy on a third unregulated region. At the sectoral level, the aggregation is limited by model constraints. However, the scheme is designed to isolate sectoral producing energy and non-energy (footloose) polluting intermediates. The first category includes Coal Petroleum and Gas products, the second, Metals, Pulp and Paper, and Chemicals, Plastic, and Rubber. The intermediate commodity “i” is used in the final production of “j”. The GTAP data derives from various sources. IO data derives from country statistical offices and is classified according to the International Standard Industry Classification (ISIC). Data on bilateral trade flows derives from COMTRADE, a database provided by the United Nations Statistical Office (UNSO), a protection data from the World Trade Organization(WTO). Data drawn from various sources is reconciled using FIT and RAS procedures.

### 3.5.2 Calibration and Parameterization

Policy outcomes are highly sensitive to model parameters. Specifically, the degree to which policy changes affect various model components is determined by the parameters defined in the behavioral equations. For instance, the size of elasticities of substitution at each stage of production determines the ease of switching from one input source to another. Importance of parameters is not restricted to substitution; expenditure shares determine the consumer post-shock allocation of goods.

In the GTAP database, substitution elasticities derive mainly from econometric and engineering studies. For parameters not contained in the database or the literature, values are determined by calibration. While not common, parameters are also determined by making educated guesses consistent with theory. In this thesis, parameters derive from GTAP, the literature and econometric estimation.

Calibration is the process of determining model parameters so that calculated values replicate the baseline equilibrium. Calibrated parameters depend on the choice of functional form and the SAM data. For instance, for Cobb Douglas preferences this entails using expenditure and income data to calculate share parameters. Equation 3.9 depicts the calibration of Cobb Douglas share parameters:

$$\alpha_i = \frac{P_i X_i}{Y} \quad (3-9)$$

While engineering and econometric studies are important sources of parameters, such parameters are based on partial equilibrium analysis thus contradicting the notion of general equilibrium. Further, concerns about parameters obtained from the literature extend to environmental damage values, which according to Perroni and Wiggle (1997), are based on willingness to pay, a subjective concept. Similarly, some are based on surveys where restrictions of CGE are not imposed for instance. To ensure that results of the simulations are robust, sensitivity analysis is carried out by varying values key parameters. Table 3.4 outlines the key parameters and the sources. Because of dimensionality constraints, I omit

actual values from the description of the model parameters

### 3.5.3 Market Structure

To model imperfect competition, I augment database adding scale and market concentration parameters both obtained from Elbehri and Hertel (2004). Elbehri and Hertel use the Herfindahl Hirschman indecies as measures of market concentration. These enter the database as parameters. In addition, add data on scale economies and an indicator or imperfect competition where a value of one means the firm if oligopolistic and zero, perfectly competitive. I use Armington the elasticities and market shares to calibrate industry elasticities. The latter is then used to calculate markups. Average costs are determined by the model in the baseline equilibrium. Finally, the marginal costs are calibrated via the Lerner equation.

### 3.5.4 Emissions Data

The GTAP database does not include information on emissions of criteria air pollutants.<sup>15</sup> While the study of criteria air emissions is important, the emission data in the literature is predominantly carbon related. Moreover, the limited number of studies that address input generated emissions focus mainly on primary factor generated emissions. In chapter 2, the literature reveals that a significant percentage of emissions is generated by the use of a small set of intermediate inputs (Benarroch and Weder, 2003; Bovernberg et al. 1996; Dessus et al. 2002a; Poterba and Rothenberg, 1995). Because the limited data on criteria air emission, I calculate air emissions endogenously using econometrically estimated intermediate input emission coefficients.

To preserve the integrity of the GTAP data, emissions are introduced into the model via emission coefficients and abatement parameters. To estimate emission coefficients, I

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<sup>15</sup>Sulfur Dioxide ( $SO_s$ ), Nitrogen Oxides ( $NO$ ), Carbon Monoxide ( $CO$ ), Particulate Matter ( $PM$ ), Voluntary Organic Compounds ( $VOC$ ) and Lead. these pollutants present serious health hazards and as a consequence increase mitigation and health care expenditures.

use data from various sources: EUROSTAT, the US Energy Information Administration (EIA), The US Environmental Protection Agency (EPA), and The US Bureau of Economic Analysis (BEA). The data on intermediate goods from the BEA has been normalized to physical inputs by dividing the commodities by the Producer Price Index (PPI) from the Bureau of Labor Statistics. Using data on intermediate consumption from the preceding data bases and emission data from EUROSTAT and the EPA, the emission coefficients are estimated using Ordinary Least Squares (OLS) estimation. Table 3.5 below presents the additional parameters used to model pollution taxes and emissions.

### **3.6 Model Implementation**

The model is implemented using the General Equilibrium Modeling Package (GEMPACK) developed by the Center for Policy Studies (COPS) at the University of Victoria. In GEMPACK, model implementation involves three steps. First, equations are specified in the theoretical model and written into a program called TABLO. The Tablo program transforms equations specified in the theoretical model into binary files readable by GEMPACK. Second, model data, solution method, closure, and shocks are specified in a command file, which is used to run the simulation via the program GENSIM. Third, results processed using SLOTH and AnalyzeGE. GEMPACK uses single or multi-step solution methods which include multi step Euler, Johansen, and Gragg methods. The choice of solution method depends on the structure of the model and the desired level of accuracy. The three step Gragg is used here because it is considered to have the highest accuracy.

### **3.7 Conclusion and Limitations of Methodology**

This chapter discusses the CGE methodology. I pay particular attention to the evolution of CGE modeling to highlight its relevancy to the current trade environmental policy research landscape. Further, I discuss the salient features of CGE modeling: the process of

nesting; the multi-stage decision-making process, the importance of functional forms and why demand side modeling prefers the more flexible functional forms and the treatment of international trade. Finally, I clarify issues of macro closure and welfare.

Moreover, I elaborate the main modification made to the model and GTAP database. In particular, the incorporation of air emissions, corrective second best taxes, and disutility from pollution. To preserve the integrity of the data, new data are introduced via parameters. Parameters are central to the outcomes of the policy simulations. In the latter part of this chapter, I discuss the three sources of CGE parameters: econometric and engineering studies, calibration and making theory consistent educated guesses. It is worth mentioning that only the first two sources are used in this thesis. Perhaps the main limitations of this methodology arise from the process of parameter determination. Parameters obtained from the literature derive from partial equilibrium studies. Further, the methodology used to estimate them may not conform to CGE assumptions.

## Appendix 3.A

Table 3.4: Extended Model Parameters

| Parameters    | Description                | Value              | Source                             |
|---------------|----------------------------|--------------------|------------------------------------|
| $\theta$      | MCPF                       | 1.9 (EU)           | Barrios et. al (2013) <sup>a</sup> |
|               |                            | 1.5 (Finland       | Dixon et al.(2012) <sup>b</sup>    |
|               |                            | 1.252 (US)         | B and G (1996) <sup>c</sup>        |
|               |                            | 1.76- 1.56 (US)    | Ballard et al. (1985) <sup>d</sup> |
| $\lambda$     | Marginal Utility of Income | 1.2                | Layard et al. (2008) <sup>e</sup>  |
| $\gamma$      | Abatement Efficiency       | 0.5                | Goulder et al.(1998) <sup>f</sup>  |
| $\alpha_{ef}$ | Effectiveness of Abatement | $1.44 \times 10^4$ | Goulder et al.                     |
| $\gamma_{va}$ | Emission Coefficients      | 0.41               | Estimated by Halstein              |
|               |                            | 0.59               |                                    |
|               |                            | 0.40               |                                    |
|               |                            | 0.07               |                                    |
|               |                            | 0.05               |                                    |
|               |                            | 0.43               |                                    |

<sup>a</sup> Marginal Cost of Public Funds (MCPF), Barrios, Pycroft and Saveyn (2013)

<sup>b</sup> Dixon, Honkatukia and Rimmer (2012)

<sup>c</sup> Bovernberg and Goulder (1996)

<sup>d</sup> Ballard, Shoven and Whalley (1985)

<sup>e</sup> Layard, Mayraz and Nickell (2008)

<sup>f</sup> Goulder, Parry, Williams and Burtraw (1998)

Table 3.5: Key Model Parameters

| Symbol         | Description                                  | Dimension | Source                    |
|----------------|----------------------------------------------|-----------|---------------------------|
| $\sigma_Q$     | Top level elasticity of substitution         | $t$       | Elbehri and Hertel (2004) |
| $\sigma_{va}$  | Elasticity of substitution- primary inputs   | $t$       | GTAP                      |
| $\sigma_{pol}$ | Elasticity of substitution- polluting inputs | $vx1$     | GTAP                      |
| $\sigma_{arm}$ | Armington elasticity of substitution         | $t$       | GTAP                      |
| $\sigma_{cet}$ | Elasticity of transformation                 | $t$       | GTAP                      |
| $\vartheta$    | CDE expansion parameter                      | $tXr$     | GTAP                      |
| $\rho_{cde}$   | CDE elasticity of substitution               | $tXr$     | GTAP                      |

# Chapter 4

## ENVIRONMENTAL POLICY COOPERATION AND TRADE

### The Case of Asymmetric Regions and Perfect Competition

*“Direct interdependence between  
two processes arises when the output of  
one becomes an input to another.”*

Wassily Leontief

#### 4.1 Introduction

The idea of linking environmental policy cooperation to issues of mutual interest derives from the notion that the desire to maintain key areas of cooperation is likely to deter free riding or strategic actions. Issue linkage considerations are becoming increasingly important and relevant as international markets become more integrated. International trade is one key area of cooperation that is likely to change behaviour. Trade is not only central to the functioning of an economy, but also provides efficiency gains that can potentially offset regulatory costs. While a number of theoretical studies support the position, little has been done to instigate whether free trade does in fact cushion costs of collective regulatory policy. Further, the literature fails to consider how these predictions are influenced by the regulatory target, regulatory approach, and labour market considerations. In addition, studies on production related emissions focus on either the direct emission regulation or indirect regulation of primary input use.<sup>1</sup> Despite the evidence that a significant proportion

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<sup>1</sup>Direct emission regulation, while targeted, has limited coverage because of the difficulty in measuring non-point -source emissions. Regulation of primary input use has broader coverage and has lower institutional costs.

of production generated emissions derive from the use of a small set of intermediate inputs (Benarroch and Weder, 2006; Dessus et al. 2002; Poterba and Rothenberg, 1999), studies investigating emission control via the user cost of intermediate inputs are limited. Now, intermediate inputs account for 45 percent of production and 56 percent of global commodity flows. Therefore, regulatory policy targeting intermediate use is likely to garner behavioural changes, and to be influenced by trade policy changes.

This chapter offers an empirical perspective on trade linked environmental policy by quantifying the effects of corrective taxes on polluting intermediate inputs between two asymmetric regions competing in perfectly competitive markets. I quantify and compare the effects of coordinated and harmonized environmental taxes under varying trade and labour market assumptions. The overarching objective is to explore how positive trade concessions, through free trade, affect joint regulatory outcomes. By drawing comparisons between coordinated and harmonized environmental taxes, I demonstrate how costs of joint policy are influenced in part, by the regulatory approach. In addition, I draw contrast between short-medium and long run outcomes of trade linked regulatory policy. To this end, I use an augmented static CGE model of trade and the environment to simulate the effects of corrective taxes on output, trade and welfare under conditions of Constant Returns to Scale (CRTS) and perfect competition.

The call for cooperation on environmental externalities is not limited to transboundary pollution. Kox and van der Tak (1996) assert that local emissions have transnational implications. Krutilla (1991) argues that the benefits of free trade cannot be fully realized without cooperation on environmental issues. Benefits of free trade can be elusive because countries can potentially use environmental policy to influence trade flows. Therefore, combining trade concessions with some sort regulatory cooperation can potentially reduce inefficiencies associated with the uneven application of environmental interventions. The literature on trade-linked regulatory policy suggests that under the right conditions, trade concessions can restructure incentives in favour of cooperation. Barrett (1997) shows that credible threats can increase the strategic space for cooperative policy. Turunen-Red and Woodland state that when Terms of Trade (TOT) are sensitive to regulatory policy,

the effects of free trade equal direct monetary transfers. Others like Bohringer et al. (2008) posit that regulatory policy can “pay” for itself through free trade.

The use of taxes as an instrument to control pollution has received considerable attention in the literature. This is because by increasing the user cost of polluting, taxes influence incentives, and therefore, have the potential to foster behavioral changes. Notwithstanding, the literature on environmental taxes is skewed towards emission control. While targeted, emission taxes encompass only point source emissions, leaving out non-point source emissions, which are a significant contributor to emissions. Further, institutional requirements of emissions taxes tend to be high. The majority of emissions based studies focus of atmospheric emissions. while climatic studies are important, they ignore emissions of criteria pollutants.<sup>2</sup>

An alternative approach would be to target polluting inputs, specifically intermediate inputs. The latter have broader coverage (source and non-point source) and can achieve the same objectives with lower institutional requirements. Poterba and Rothenberg (1995) further suggest that a pragmatic approach to pollution control would be to tax small set of intermediate goods responsible for the bulk of emissions. Dessus et al. (2002) find that 90 percent of the variation in emissions can be explained by a set of less than 10 intermediate inputs. Moreover, intermediate inputs account for approximately 45 percent of production input requirements and 56 percent of global trade (OECD, 2009). For this reason, policies targeting intermediates are likely to have significant impacts on production choices, long-term productivity and trade. Importantly, taxes on polluting intermediates can be decisive instruments in international environmental policy design and cooperation. It is worth mentioning that most environmental taxes currently implemented are in actual sense taxes on intermediates (Poterba and Rothenberg, 1995). Despite these observations, little attention has been paid to the study of pollution control via intermediate input use, and in particular collective policy. Studies on input use generated emissions tend to focus on primary inputs.

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<sup>2</sup>Criteria emissions tend to have significant health effects and therefore, have important implications for health care costs

The literature on the effects regulatory taxes suggests that combining environmental taxes with free trade can be welfare improving. Among the few theoretical studies on intermediate input based pollution, Gallegos (2005) finds a policy that combines free trade with a first best optimal tax scheme maximizes welfare. Further, in the absence of free trade, a more stringent policy stance can improve welfare. Empirical studies on environmental taxes and free trade in perfectly competitive markets predict that policies that combine the two are welfare improving. Roland-Holst and Bussolo (2002) point to the potential welfare gains from combining regulatory tax with trade liberalization. They find environmental policy in the absence of free trade to have negative growth effects. Similarly, using an asymmetric CGE model with population and income based asymmetries, El Obeid, Mensbrugghe and Dessus (2002) find regulatory schemes that combine environmental taxes with free trade to have positive welfare effects. Further, Adkins and Garbaccio (2007) use the GTAP model with 21 regions and labour market distortions; they find that although emission tax can offset gains from free trade, welfare in all regions increases.

Trade effects of environmental taxes when markets are perfectly competitive have been extensively studied in the literature; however, results are inconclusive. One strand finds regulatory taxes to have negative trade effects (Ederington and Minier, 2003; van Beers and van den Berg, 2000; Krutilla, 1991).<sup>3</sup> Others like Cole and Elliot (2003), Harris et al. (2002), van Beers and van den Berg (1997) and Tobey (1990) find no correlation between regulatory stringency and aggregate trade flows. While the two strands of literature agree that regulatory stringency can have sectoral effects, none of them discusses the regulatory approach. Moreover, they ignore the effects of labor market characteristics.

The failure of global climatic initiatives warrants a piecemeal approach to policy cooperation and an understanding the implications various regulatory approaches. Another decisive issue is whether to harmonize or coordinate environmental taxes. The former requires the implementation of uniform taxes while the latter specifies the criteria and allows regions to set their taxes. Literature on the effects of these approaches is mainly theoretical

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<sup>3</sup>Krutilla (1991) finds that a regulatory tax cum free trade has negative export and trade effects if the regulating country is a net exporter of the regulated good. If instead, the region is a net importer, then the opposite is true

and inconclusive. Some studies argue that there are no efficiency gains to environmental policy cooperation (Hoel, 1997), while others contend that under the right conditions, policy harmonization can result in welfare gains (Turunen-Red and Woodland, 2004; Vlasiss, 2012; Cheickbossian, 2010).

This chapter makes four main contributions to the literature. First, I extend the existing literature by quantifying and comparing effects of policy harmonization and cooperation between two asymmetric trading partners competitive under conditions of CRTS and perfect competition. Further, I model intermediate generated pollution and corrective taxes in the CGE context. In addition, I compare regulatory outcomes in the absence and presence of free trade to ascertain the importance of combining environmental policy and tariff reduction. I incorporate labour market considerations into the analysis of environmental policy cooperation and trade.

As a starting point, I answer the following questions: What effect do taxes regulating polluting intermediates have on output trade and welfare? How do the policy outcomes differ when policies are harmonized or coordinated? How does the removal of trade taxes affect policy outcomes? Finally, are labour market considerations important determinants of effects of cooperative regulatory policy?

To this end, I extend the standard GTAP model to include intermediate based emissions, environmental taxes, disutility from pollution and a four level nest describing substitution possibilities between polluting intermediates. I find that the effects of either regulatory approach on output depend largely on whether capital and regulated inputs are complements or substitutes. Further, output effects are more pronounced when taxes are harmonized, the real wage of unskilled labour is fixed and there is no free trade. Specifically, the larger region, the EU, experiences adverse output and welfare outcomes from harmonizing environmental taxes in the absence of free trade. In contrast, the smaller region, Canada, experiences minor welfare losses when taxes are coordinated in the absence of free trade. While free trade offsets regulatory costs in EU, it has mixed effects on Canada. In fact, when environmental taxes are coordinated, free trade exerts sizable costs on the region. The

effects of regulatory policy on trade flows seem to support earlier studies that regulatory policy has no significant effect on trade flows and competitiveness. Nonetheless, results from these studies derive mainly from partial equilibrium analysis.

The chapter follows the following structure: Section 4.2 presents the formal model. Section 4.3 discusses chapter specific data and model applications. Section 4.4 explains the simulation design. Section 4.5 presents and discusses the simulation results. Section 4.6 concludes.

## 4.2 The Model

### 4.2.1 Production

Each sector produces a single tradable homogeneous commodity ( $Q_i$ ) that satisfies final and intermediate demand. Production is described by a nested Constant Elasticity of Substitution (CES) structure, where firms choose a cost minimizing input combination at each stage given the factor prices. The latter, are determined by marginal productivity and are subject to indirect taxes. Two input categories are used in the production process, (a) primary endowments and (b) intermediate commodities. The former consist of Capital (K), Resources (N) and Labor (L); where labor is divided into skilled and unskilled classes. All endowments are sourced from a representative household. The three endowments are collectively termed Value Added (VA) factors. Intermediate commodities ( $Q_{i,j}$ ) are sourced from both domestic and foreign market based on the Armington specification, are considered imperfect substitutes on the basis of origin. The use of intermediates in production generates emissions, and here we borrow Gallegos (2005) terminology of emissions by industrial consumptions. Specifically, six of the ten intermediates are polluting.

Firms across regions are identical in all aspects. Their objective is to minimize costs by choosing input combinations at stage. Figure 4.1, illustrates the four level nested production process. The top (first) level nest describes how gross output in region  $r$  ( $Q_{i,r}$ ) is produced

using a cost minimizing combination of a VA and intermediate composite. Assuming that the two composites are substitutes, the firm's top level cost minimization problem is:

$$\text{Min} P_{(va)i,r} Q_{(va)i,r} + P_{i,j,r} Q_{i,j,r} \quad (4-1)$$

such that

$$Q_{i,r} = [\alpha_{(va)i,r} q_{(va)i,r}^{\rho_Q} + \alpha_{i,j,r} Q_{i,j,r}^{\rho_Q}]^{1/\rho_Q} \quad (4-2)$$

Equation 4-1 represents the firm's objective function. It represents the cost of producing gross output of commodity  $i$  in region  $r$  ( $Q_{i,r}$ ) using the combination of an Armington intermediate composite ( $Q_{(va)i,r}$ ) and the value added composite ( $Q_{i,j,r}$ ) at input prices  $P_{(va)i,r}$  and  $P_{i,j,r}$ . The firms choose the combination of the value added and intermediate composite given a nested CES technology described by equation 4-2. Equation 4-2 represents substitution possibilities in the first level nest. Here, the parameters  $\alpha$  and  $\rho$  are the share and substitution parameters. The latter is related to the elasticity of substitution ( $\sigma$ ) by  $\sigma_Q = \frac{1}{1-\rho_Q}$ . The elasticity of substitution is central to determining the extent of policy shock transmissions within sectors. Figure 4-1 illustrates substitution possibilities at different levels of the production structure.

Shepherd's Lemma and the Envelope Theorem yield conditional demands for the value added and intermediate composites defined by equations 4-3 and 4-4. The cost minimizing decomposition of the two input composites occurs at the second level nest illustrated in figure 4-1. The conditional demand for value added and intermediates are determined by gross output ( $Q_{i,r}$ ), the input share parameter  $\alpha$ , the elasticity of substitution ( $\sigma_Q = \frac{1}{1-\rho_Q}$ ) and relative prices of the input and gross output,  $P_{i,r}$  and  $P_{(*)i,r}$ .

$$Q_{(va)i,r} = \alpha_{(va)i,r} \left( \frac{P_{i,r}}{P_{(va)i,r}} \right)^{\sigma_Q} Q_{i,r} \quad (4-3)$$

$$Q_{i,j,r} = \alpha_{i,j,r} \left( \frac{P_{i,r}}{P_{i,j,r}} \right)^{\sigma_Q} Q_{i,r} \quad (4-4)$$

$$P_{i,r} = [\alpha_{(va)i,r} P_{(va)i,r}^{1-\sigma_Q} + \alpha_{i,j,r} P_{i,j,r}^{1-\sigma_Q}]^{1/(1-\sigma_Q)} \quad (4-5)$$

The value added composite consists of four primary inputs: capital (K),resources (N), high skill (skl) and low skill(uskl) labour. The four inputs enter the second level nest as capital-resource and labour composites. The second level nest groups the four into two composite inputs, capital-resource (KN) and labour (L). This specification allows for the isolation of the shock impacts on labour in general. Equations 4-6 to 4-8 describe the value added nesting processes. Given the set of factor and output prices the firm chooses the cost minimizing combination of labour and the capital-resource composite given CES technology:

$$Min \ P_{(KN)i,r} KN_{i,r} + W_{i,r} L_{i,r} \quad (4-6)$$

such that

$$Q_{(va)i,r} = [\alpha_{kn)i,r} (N_{i,r}^{\rho_{kn}} + N_{i,r}^{\rho_{kn}})^{\rho_{va}} + \alpha_l (l_{skl}^{\rho_l} + l_{ul}^{\rho_l})^{\rho_{va}}]^{\frac{1}{\rho_{va}}} \quad (4-7)$$

where  $P_{kn}$  and  $W_{i,r}$  are the capital-resource composite price and the average sectoral wage.  $\alpha_{va}$  and  $\alpha_l$  are value added share parameters, and  $\rho_{va}$ ,  $\rho_{kn}$  and  $\rho_l$  are the value added, capital-resource and labour substitution parameters.

Equations 4-8 through 4-12 describe the resulting conditional demands at the third level nest. The conditional demand are determined by the unit value added cost ( $C_{(va)i,r}$ ), individual input prices ( $P_{(k)i,r}$ ,  $P_{(n)i,r}$ ,  $W_{(skl),r}$  and  $W_{(ul)i,r}$ ), share All four inputs are sec-

torally mobile but non tradable.

$$KN_{i,r} = \alpha_{kn} \left( \frac{\alpha_{va} C_{(va)i,r}}{P_{(kn)i,r}} \right)^{\sigma_{va}} Q_{va} \quad (4-8)$$

$$L_{i,r} = \alpha_L \left( \frac{\alpha_{va} C_{(va)i,r}}{W_{i,r}} \right)^{\sigma_{va}} Q_{(va)i,r} \quad (4-9)$$

Following Magnus (1979) and Borges and Goulder (1984), Capital(K) and the Resource(N) inputs are used in fixed proportions ( $\sigma_{kn} = 0$ ). Capital is homogeneous, sectorally and regionally mobile and is sensitive to the expected rate of return in the global capital bank. The latter is included in the price of capital (the rental rate of capital),  $P_{(K)i,r}$ . These assumptions imply that divergences in capital will induces a flow of capital from one sector/region to another until the expected rate of return is equalized across regions. The resource endowment is fixed and sector specific. Equations 4-10- to 4-13 represent inputs at the third level value added sub-nests.

$$K_{i,r} = \alpha_k \left[ \frac{\alpha_{kn} P_{(kn)i,r}}{P_{(k)i,r}} \right]^{\sigma_{kn}} KN_{i,r} \quad (4-10)$$

$$N_{i,r} = \alpha_n \left[ \frac{\alpha_{kn} P_{(kn)i,r}}{P_{(N)i,r}} \right]^{\sigma_{kn}} KN_{i,r} \quad (4-11)$$

$$L_{(skl)i,r} = \alpha_{skl} \left[ \frac{\alpha_L W_{i,r}}{W_{(skl)i,r}} \right]^{\sigma_L} L_{i,r} \quad (4-12)$$

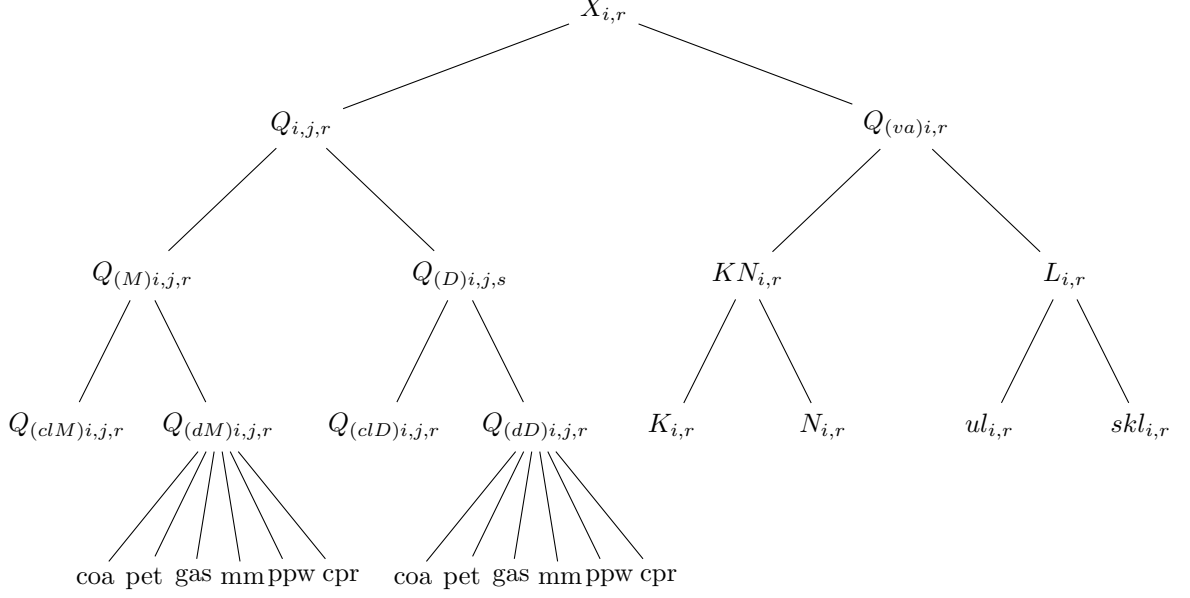
$$L_{(ul)i,r} = \alpha_{ul} \left[ \frac{\alpha_L W_{i,r}}{W_{(ul)i,r}} \right]^{\sigma_L} L_{i,r} \quad (4-13)$$

Where  $\alpha_{ul}$  and  $\alpha_{skl}$  are share parameters such that  $\alpha_{skl} > \alpha_{ul}$ .

Equations 4-12 and 4-13 depict the conditional demands for labor by skill type. The restriction on the share parameters is a simplification because the distribution of shares is sector specific. Both labour types are inter-sectorally mobile. The unit labor cost (average wage)  $W_{(i,r)}$  is the weighted average rate of the skilled wage rate  $W_{(skl)i,r}$  and the unskilled

rate  $W_{(ul)i,r}$ , where each wage category is weighted by the share parameters. The total labor endowment expressed as the sum of the two skill categories is fixed at regional level.

Figure 4.1: Production Nesting



The intermediate composite is a combination of intermediates sourced in the domestic ( $Q_{(D)i,j,r}$ ) and foreign markets ( $Q_{(M)i,j,r}$ ). The two are considered imperfect substitutes on the basis of origin, a la Armington. For simplicity, I assume that the elasticity of substitution between intermediate inputs from both the ROW and region r to equal the Armington substitution elasticity between region i's domestic and imported intermediates ( $\sigma_{arm} = \sigma_{r,row}$ ). Equations 4-14 and 4-15 express the firm's cost minimizing choice corresponding to the intermediate input sub-nest in figure 4-1.

$$\text{Min } P_{(M)i,j,s} Q_{(M)i,j,s} + P_{(D)i,j,r} Q_{(D)i,j,r} \quad (4-14)$$

such that

$$Q_{i,j,r} = (\alpha_M (Q_{(clM)i,j,r}^{\rho_{dcl}} + Q_{(dM)i,j,r}^{\rho_{dcl}})^{\rho_{arm}} + \alpha_D (Q_{(clD)i,j,r}^{\rho_{dcl}} + Q_{(dD)i,j,r}^{\rho_{dcl}})^{\rho_{arm}})^{\frac{1}{1-\rho_{arm}}} \quad (4-15)$$

Sherpherd's Lemma and the envelope theorem yield conditional Armington demand

function's 4-16 and 4-19. The import composite given by 4-16 is a combination of clean ( $Q_{(clM)i,j,s}$ ) and dirty ( $Q_{(dM)i,j,s}$ ) sourced from foreign markets. Likewise the domestic composite 4-19, is a combination of clean ( $Q_{(clD)i,j,r}$ ) and dirty ( $Q_{(dD)i,j,r}$ ) sourced internally.

$$Q_{(M)i,j,r} = \alpha_{(M)} \left[ \frac{\alpha_{i,j,r} C_{i,j,r}}{P_{(M)j,j,r}} \right]^{\sigma_{arm}} Q_{i,j,r} \quad (4-16)$$

$$Q_{(clM)i,j,r} = \left[ \frac{\alpha_{(M)i,j,r} P_{(M)i,j,r}}{P_{(clM)j,j,r}} \right]^{\sigma_{arm}} Q_{Mi,j,r} \quad (4-17)$$

$$Q_{(dM)i,j,r} = \left[ \frac{\alpha_{(M)i,j,r} P_{(M)i,j,r}}{P_{(dM)j,j,r}} \right]^{\sigma_{arm}} Q_{Mi,j,r} \quad (4-18)$$

$$Q_{(D)i,j,r} = \alpha_{(D)} \left[ \frac{\alpha_{i,j,r} C_{i,j,r}}{P_{(D)j,j,r}} \right]^{\sigma_{arm}} Q_{i,j,r} \quad (4-19)$$

$$Q_{(clD)i,j,r} = \left[ \frac{\alpha_{(D)i,j,r} P_{(D)i,j,r}}{P_{(clD)j,j,r}} \right]^{\sigma_D} Q_{Di,j,r} \quad (4-20)$$

$$Q_{(dD)i,j,r} = \left[ \frac{\alpha_{(D)i,j,r} P_{(D)i,j,r}}{P_{(dD)j,j,r}} \right]^{\sigma_D} Q_{Di,j,r} \quad (4-21)$$

where  $\alpha_{i,j,r}$ , represents the share of intermediate inputs in gross output,  $\alpha_M$  and  $\alpha_D$ , the import and domestic Armington share parameters. Likewise,  $\sigma_{arm}$  and  $\sigma_D$  represent the Armington and domestic elasticities of Substitution.

The fourth level intermediate sub-nest describes substitution possibilities between dirty intermediates ( $Q_{(v)i,j,r}$ ). These include energy based intermediates coal, petroleum (pet) and gas, and non-energy polluting intermediates metals and minerals (mmm), pulp and paper(ppw) and chemicals, plastics and rubber(cpr). All six dirty intermediates are traded internationally; the non-tradable sector consists of primary factors that make up the value added composite. The prices paid for these inputs includes pre-existing input taxes plus a per-unit environmental tax ( $\tau_{E,V}$ ). The environmental tax is applied in the destination country and under free trade, the dirty intermediate from domestic and foreign suppliers

are subject to the same price. The fourth level nest in figure 4-1 illustrates the substitution possibilities between the six polluting intermediate input. Equation 4-22 determines sectoral air emissions associated with the use of the dirty inputs. For simplicity, I use a general specification as opposed to pollutant-specific air emissions. Borrowing from Goulder, Parry, Williams and Burtraw (1998), sectoral air emissions associated with the use of polluting input  $Q_{(v)i,j,r}$  are defined by:

$$E_{v,r} = \sum_{j=1}^{10} \psi_v q_{v,j,r} \left[ 1 - \alpha_{ef} \left( \frac{C_{abt,j}}{\psi_v q_{v,j,r}} \right)^\gamma \right] \quad (4-22)$$

Where  $\delta\psi, \delta\alpha_{ef}, \delta\gamma = 0$  and  $\delta C_{abt} < 0$

Total regional emissions associated with the use of input i,  $E_{v,r}$ , are dependent on emissions per-unit dirty input  $\psi_v$ , the amount of dirty input used ( $q_{v,j,r}$ ) and abatement (the term in the smooth brackets). Abatement per unit output ( $C_{abt,j}$ ) is the ratio of abatement expenditure in sector j total output,  $\alpha_{ef}$  is the effectiveness of technology and  $\gamma$ , the curvature of the abatement technology ; which, according to the authors, is less than 1.<sup>4</sup> Assuming that firms initially make an investment in abatement technology,  $C_{abt,j}$  falls as output expands. The impact of any shock to the dirty intermediates will depend on the level of output, the quantity of polluting factor, the relative importance of dirty intermediates in total production and the emission intensity of inputs.

Following Bovernberg and Goulder (1996), I define the second best optimal environmental tax on a dirty intermediate as:

$$\tau_E^{opt} = \left[ \frac{\left( \frac{\delta U_r}{\delta q_{v,r}} \right) \frac{-\delta E_{v,r}}{\delta q_{i,r}}}{\lambda_r} \right] \frac{1}{\theta_r} \quad (4-23)$$

Where  $\theta_r = \frac{\text{Shadow price of public funds}}{\text{Marginal utility of private income}}$ , is the Marginal Cost of Public Funds (MCPF),  $\lambda_r$ , the Frisch Parameter (the marginal utility of income) and  $U_r$ , the per-capita utility of the regional household. The term in the square brackets is the Marginal External Damage

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<sup>4</sup>According to Goulder et al. (1998), this specification preserves the homogeneity of the emissions function

(MED).<sup>5</sup>

The process of production nesting begins with the determination of prices from the bottom to the top nest and then determination of conditional input demands at each nest. The top level composite cost, therefore, includes the policy variable  $\tau_E$ . This obvious detail is worth mentioning because, firms will respond to a policy shock by either (a) input substitution or (b) output changes, or both.

### Output Allocation

Firms maximize revenue given commodity and factor prices by selling output in domestic and foreign markets. The allocation of output is determined by the Constant Elasticity of Transformation (CET) nesting structure. This follows the Armington convention where transformability between domestic and foreign sales is assumed to be imperfect. Revenue maximization problem 4-24 to 4-25 determines the relative export and domestic supply functions.

$$P_{cet}Q_{i,r} = P_{(DS)}Q_{(DS)i,r} + P_{(EX)}Q_{(EX)i,r} \quad (4-24)$$

$$Q_{(cet)i,r} = [\alpha_{(cet)i,r}Q_{(EX)i,r}^{\rho_{cet}} + (1 - \alpha_{(cet)i,r})Q_{(DS)i,r}^{\rho_{cet}}]^{1/\rho_{cet}} \quad (4-25)$$

where,  $Q_{(DS)i,r}$  represent domestic supply and  $Q_{(EX)i,r}$  exports,  $P_{cet}$  the composite CET price,  $\alpha_{cet}$ , the share parameter and  $\rho_{cet}$ , the transformation parameter. The latter determines the transformation elasticity ( $\sigma_{cet}$ ) through the equation  $\sigma_{cet} = \frac{1}{1+\rho_{cet}}$ . CET supply functions:

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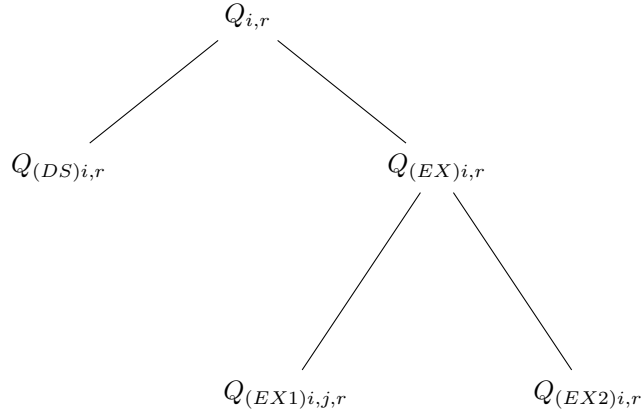
<sup>5</sup>The shadow price of public funds measures the cost to society of raising a dollar of tax revenue. The marginal Utility of Private expenditure measures the private cost of having a dollar more to spend (Gavahri, 2004).

$$Q_{(DS)i,r} = \alpha_{cet} \left[ \frac{P_{(cet)i,r}}{P_{(DS)i,r}} \right]^{\sigma_{cet}} Q_{i,r} \quad (4-26)$$

$$Q_{(EX)i,r} = \alpha_{cet} \left[ \frac{P_{(cet)i,r}}{P_{(EX)i,r}} \right]^{\sigma_{cet}} Q_{i,r} \quad (4-27)$$

According equations 4-24 and 4-25, domestic sales and exports depend of relative prices and share and substitution parameters. In this thesis, I assume a non-nested CET structure. The transformation between exports destined to regions “s” and the ROW equals the elasticity of transformation between domestic and exports.

Figure 4.2: CET Transformation of Domestic Supply and Exports



#### 4.2.2 Final Demand

A separable per-capita Cob-Douglas Utility function  $U_r$  describes the regional household's final demand. The regional household seeks to minimize expenditure (4-28) on private and government consumption, savings and pollution damage mitigation. Therefore, pollution

generated by industrial consumption enters the regional utility function (4-29).

$$P_r X_r = E_h(P_h, U_h) + E_g(P_g, U_g) + P_s S + P_{pol} D_{pol} \quad (4-28)$$

$$U_r = U_h^{\beta_h} U_g^{\beta_g} S^{\beta_s} Z^{-\phi} \quad (4-29)$$

Where the regional price  $P_r$  index is an expenditure share weighted index of the average price of private and government consumption, price of savings and the shadow price of pollution, and  $X_r$ , total output produced in region r.  $P_h$  and  $P_g$  are price vectors,  $P_s$  the price of savings and  $P_{pol}$  the shadow price of pollution.  $\beta_s$  are the elasticity parameters and  $\phi$  the elasticity of disutility with respect to regional utility. Finally,  $U_p$ ,  $U_g$ ,  $S$  and  $Z$  represent private household utility, government utility, savings and pollution damages.

Three restrictions apply to the above specification. First, savings and damages are treated as commodities. Second, government sub-utility is Cob Douglas. Finally, private household preferences are non-homothetic. The latter is imposed to allow for changing budget shares are income and prices change. The general depiction of the regional expenditure function and three of the above restrictions derive from McDougall (2003). Based on the assumption of cardinality of the regional utility function, Hertel (2001) and McDougall (2003) introduce the concept of expenditure elasticity of utility as a factor explaining shifts in the regional utility function. They make a further assumption of unitary government and savings expenditure elasticities.

## Government Demand

Government generates income from income, factor and commodity taxes. It spends this income on domestic and imported commodities, and transfers a lump-sum to the regional

household. Government preferences are Cobb-Douglas:

$$U_{g,r} = X_{(D)i,r}^{\beta_g} X_{(M)i,s}^{1-\beta_g} \quad (4-30)$$

$$Y_{(g),r} - T_r = P_{(gD)i,r} X_{(gD)} + P_{(gM)i,s} X_{(gM)i,s} \quad (4-31)$$

The usual restrictions of constant budget shares, unitary income elasticities, unitary own price elasticities and zero cross-price elasticities apply.

#### 4.2.3 Private Household Demand

Private household preferences are given by the CDES minimum expenditure:

$$E(P, U) = \sum_{i=1}^{10} B_i U_{(h)i,r}^{\vartheta \rho_{cde}} \left[ \frac{P_{(h)i,r}}{P_{(h)} X_{(h)r}} \right]^{\rho_{cde}} \equiv 1 \quad (4-32)$$

where  $B$  and  $\vartheta$  are non-negative, and  $\rho_{cde}$  is either less than 1 for all none-negative values or less than zero for all  $i, s$ .  $U_{(h)r}$  and the term in the brackets are the private household utility and the normalized price for good “i” respectively, the numerator  $P_{(h)i,r}$ , is the highest price the consumer is willing to pay for good “i”, given price of other goods, expenditure (the denominator) and utility.  $B$ ,  $\vartheta$  and  $\rho_{cde}$  are the scale, expansion and substitution parameters.

The expansion parameter explains the non-homotheticity of the CDES function (Huff, Hanslow, Hertel and Tsigas, 1997). Further, the expansion and substitution parameters are related to the compensated and income elasticities. Solving for  $U_{(h)r}$  yields the indirect utility function as a function of normalized prices, which using Roy’s Identity and the Envelope Theorem yields the demand for the domestic commodity i (4-33). Further, pre-multiplication by the normalized price gives the expenditure share (4-34). Both equations are adopted from de Boer, Brocker, Jensen and van Daal (2006).

$$X_{(h)i,r} = \frac{B_i \left( \frac{P_{(h)i,r}}{Y_{(h)r}} \right)^{\rho_{(h)i}-1}}{\sum_{i=1}^{10} B_j \left( \frac{P_{(h)j,r}}{Y_{(h)r}} \right)^{\rho_{(h)k}}} \quad (4-33)$$

$$\Theta_{(h)i,r} = \frac{B_i \left( \frac{P_{(h)i,r}}{Y_{(h)r}} \right)^{\rho_{(h)i}}}{\sum_{i=1}^{10} B_j \left( \frac{P_{(h)j,r}}{Y_{(h)r}} \right)^{\rho_{(h)k}}} \quad (4-34)$$

Where  $Y_{(h)r} = P_{(h)r} X_{(h)r}$  and budget shares  $0 < \Theta_{(h)i,r} < 1$ ,  $\sum_{i=1}^{10} \Theta_{(h)i,r} = 1$

### Savings

Savings are a homogeneous commodity. Regional savings are gathered by a fictitious global bank to create and investment portfolio. Consequently, the savings rate is closely tied to the price of capital goods; it is region specific and adjusts with movements in the rental rate of capital.

### Disutility of Pollution

The pollution damage function  $Z(\omega, E, \lambda)$ , describes the relationship between emissions and pollution. Emissions result in pollution due to various factors such as the weather, ambient concentration and distance. The term  $\omega$ , the pollution conversion factor, captures all the processes that convert emissions into pollution. Equations 4-35 and 4-36 describe the pollution and damage function:

$$E_{pol,r} = \omega_r \sum_{v=1}^6 E_{v,r} \quad (4-35)$$

$$Z_r = \lambda_r(\omega_r, E_r) = \lambda_r E_{pol,r} \quad (4-36)$$

$\lambda_r(U, Y)$  and  $\omega_r E_r$  are the marginal utility of income, and regional pollution. Damages are therefore, the product of regional emissions and marginal utility of income.

#### 4.2.4 Prices

The price block consists of four sets of relative prices expressed in *US\$*s; composite prices, domestic commodity prices, factor prices, and international prices. In the baseline equilibrium, tax exclusive prices are normalized to one. The Real Exchange Rate (RER) is used as the numeraire.

##### Composite Prices

$$P_{i,r} = [\alpha_{va}P_{(va)i,r} + \alpha_{i,j,r}P_{i,j,r}] \quad (4-37)$$

$$P_{arm} = [\alpha_{arm}P_{(M)i,s} + (1 - \alpha_{arm})P_{(D)i,r}] \quad (4-38)$$

$$P_{cet} = [\alpha_{cet}P_{(DS)i,r} + (1 - \alpha_{cet})P_{(EX)i,r}] \quad (4-39)$$

$$P_{garm} = [\alpha_{garm}P_{g(M)i,s} + (1 - \alpha_{garm})P_{(gD)i,r}] \quad (4-40)$$

$$P_{arm} = [\alpha_{harm}P_{(hM)i,s} + (1 - \alpha_{harm})P_{(hD)i,r}] \quad (4-41)$$

$$P_{(GDPEF),r} = \frac{NGDP_r}{Q_{(VA),r}} \quad (4-42)$$

##### Commodity Prices

$$P_{(va)i,r} = P_{i,r}(1 + \tau_{(va)i,r}) \quad (4-43)$$

$$P_{(D)i,r} = P_{i,r}(1 + t_{(D)i,r}) \quad (4-44)$$

$$P_{(DS)i,r} = P_{i,r}(1 + \tau_{(DS)i,r}) \quad (4-45)$$

$$P_{(hD)i,r} = P_{(gD)i,r} = P_{(D)i,r} \quad (4-46)$$

$$P_{(s),r} = \left( \frac{I_{net}}{I} \right) P_{(k)r} \quad (4-47)$$

$$P_{(pol)r} = P_{(shdw)r} = Z' \quad (4-48)$$

Equations 4-43 to 4-48 represent tax inclusive domestic prices of commodity  $i$ . The price of savings (equation 4-47) is a function of regional investment and the price of capital. Equation 4-48 represents the shadow price of pollution, which is also the marginal damage  $z'$ .

### Real Factor Prices

$$W_{(k)i,r} = \delta Q_{i,r} / \delta K_{i,r} \quad (4-49)$$

$$P_{(k)i,r} = W_{(k)i,r} (1 + \tau_{(k)r}) \quad (4-50)$$

$$w_{(ul)i,r} = \delta Q_{i,r} / \delta L_{(ul)i,r} \quad (4-51)$$

$$w_{(skl)i,r} = \delta Q_{i,r} / \delta L_{(skl)i,r} \quad (4-52)$$

$$\bar{W}_{i,r} = [\alpha_{(ul)i,r} w_{(ul)i,r} (1 + \tau_{ul}) + \alpha_{(skl)i,r} w_{(skl)i,r} (1 + \tau_{skl})] \quad (4-53)$$

$$W_{(N)i,r} = \delta Q_{i,r} / \delta N_{i,r} \quad (4-54)$$

$$P_{(N)i,r} = W_{(N)i,r} (1 + \tau_{(N)i,r}) \quad (4-55)$$

$$r_{or(exp)r} = r_{or(k)r} \left[ \frac{K_{(2)r}}{K_{(1)r}} \right]^{\chi_r} \quad (4-56)$$

Equations 4-49 through 4-56 describe factor prices. The real price of capital, labor and natural resources are functions of the price of the rental rate of capital (4.52), real wage (4.49

– 4.50), the rental rate of natural resources (4-57) respectively and the associated ad-valorem tax rates. Equation 4-53 is the average sectoral wage, the sum of skilled and unskilled real wages weighted by their respective shares,  $\alpha_{(ul),i,r}$  and  $\alpha_{(skl),i,r}$ . Equation 4-56 defines the expected rate of return for region  $r$ . It is a function of beginning period capital ( $K_{(1)r}$ ), end period capital ( $K_{(2)r}$ ), the current rate of return on investment ( $r_{or_r}$ ) and the flexibility parameter ( $\chi_r$ ). The expected rate of return determines the flow of regional investment. Investment flows will adjust to changes in savings in the global bank until expected rates of return across regions are equalized. The flexibility parameter which is non-negative. It is the elasticity of the expected rate of return with respect to end period capital equals the the negative value of the flexibility parameters (Hertel and Tsigas, 1997).<sup>6</sup>

## International Prices

$$R_r = \frac{P_{(va)r}}{P_{(va)s}} \quad (4-57)$$

$$P_{(M)i,s} = R_r(1 + \tau_{(M)i,r}P_{(\bar{M})i}) \quad (4-58)$$

$$P_{(EX)i,r} = R_r(1 + \tau_{(EX)i,r}P_{(\bar{EX})i}) \quad (4-59)$$

$$P_{(hM)i,s} = P_{(gM)i,s} = P_{(M)i,s} \quad (4-60)$$

$$TOT_r = \frac{P_{(EX)r}}{P_{(M)s}} \quad (4-61)$$

The real exchange (4-56) rate is ratio of the price of non-tradables in region  $r$  to non-tradables in region's. In this case, the value added inputs are non-tradable, hence the real exchange rate is the relative price of the value added inputs. The price of imports is the function of the real exchange rate, the world price of imports ( $\bar{M}$ ) and the ad valorem tariff  $\tau_M$ . Likewise, the export price is a function of the real exchange rate, the world price of

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<sup>6</sup>The value of the flexibility parameter varies inversely with the sensitivity of end period capital to changes in the expected rate of return

exports ( $\bar{E}X$ ) and the export tax ( $\tau_{EX}$ ). Equation 4-61 describes Terms of Trade (TOT) as the ratio of the price of exports to imports

#### 4.2.5 Macro Closure

To capture the effects of the policy shock on the trade balance, I assume endogenous government savings and exogenous taxes. Likewise, the trade balance is endogenous and the real exchange rate is treated as exogenous. Because regulation changes the distribution of relative costs across regions, these changes are bound to affect competitiveness through their effects on trade. To accommodate these changes, the real exchange is chosen as the numeraire. Finally, I assume savings driven investment. Therefore, investment levels adjust to the expected rate of return on regional investment.

#### 4.2.6 Equilibrium Conditions

##### Commodity and Factor Market Clearance

$$\sum_{i=1}^{10} P_{(cet)i,r} Q_{i,r} = \sum_{i=1}^{10} P_{(arm)i,r} X_{i,r} \quad (4-62)$$

$$\sum_{i=1}^{10} L_{(ul)r}^D = L_{(ul)r}^S \quad (4-63)$$

$$\sum_{i=1}^{10} L_{(skl)r}^{(D)} = L_{(skl)r}^S \quad (4-64)$$

$$\sum_{i=1}^{10} K_r^D = K_r^D \quad (4-65)$$

$$\sum_{i=1}^{10} N_r^D = N_r^D \quad (4-66)$$

## Zero Profit Condition

In equilibrium all producers earn zero economic profits. For each producer, equation 4-67 states that the combined value of domestic and export sales of good  $i$  equals the total cost of producing commodity  $i$ .

$$P_{(DS)i,r}Q_{(DS)i,r} + P_{(EX)i,r}Q_{(EX)i,r} = P_{(va)i,r}Q_{(va)i,r} + P_{i,j,r}Q_{i,j,r} \quad (4-67)$$

## Incomes Balance

In equilibrium, all agents operate exhaust their budgets. Equations 4-68 to 4-69 describe government and private household income balances.<sup>7</sup>

$$\sum_{i=1}^{10} P_{(g)i,r}X_{(g)i,r} + T = Y_{(g)r} \quad (4-68)$$

$$\sum_{i=1}^{10} P_{(h)r}X_{(h)r} = \bar{W}_r(1 - \tau_L r)L_r + W_{(k)r}K_r + W_{(N)r}N_r + T \quad (4-69)$$

Equations 4-1 to 4-72 complete the formal model.

## 4.3 Application, Chapter Specific Data and Calibration

The model is applied to Canada-EU trade. The application is timely because of the recent signing of the Canada-EU Comprehensive Economic and Trade Agreement (CETA). The model is calibrated to the GTAP Vol.6 database. The database is aggregated to 3 regions, 10 sectors, and four primary factors. The three regions Canada, the EU and the Rest of the World (ROW) are chosen to isolate trade between Canada and the EU which represent

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<sup>7</sup>where  $Y_{g,r} = \tau_{(L)r}L_r + \tau_{(k)r}K_r + \tau_{(N)r}N_r + \tau_{(E)r}E_r + \tau_{(EX)r}Q_{(EX)r} + \tau_{(M)r}X_{(M)r}$

the smaller and the larger region respectively. Capital, low skill (unskilled) and high skill (skilled labour) and resources (includes land and natural resources) are the four primary products. The data is aggregated to 10 tradable sectors agriculture and food (agf), coal, petroleum (pet), gas, metals and minerals (mmm), pulp and paper (ppw), chemicals rubber and plastics (cpr), manufactures (mnfs), transport (opt) and services (svcs).

Table 4.1 lists the baseline environmental taxes. The taxes are calculated within the model using Goulder et al.'s (1998) theoretical specification of a second-best optimal tax on polluting intermediate inputs defined in this chapter by equation 4.26. According to Table 4.1, Canada's environmental taxes are significantly higher than the EU. Canada's higher taxes are mainly due to differences in Marginal External Damages (MED) and the Marginal Cost of Public Funds. The differences in the MED derive mainly from the structure of production in the two regions. Canada's production, especially in the energy sectors, is resource intensive while the EU's is capital intensive. The item in the square brackets of equation 4-26 represents the MED. Apart from the marginal utility of income obtained from Layard et al. (2008), the rest of the components of the MED are obtained from the model data. Likewise, the MCPF is obtained from various studies listed in Table 3.4 of chapter 3.

Table 4.1: Asymmetric Case Baseline Second Best Environmental Taxes

| Input | Canada | EU    | ROW   |
|-------|--------|-------|-------|
| coal  | 19.04  | 7.14  | 18.95 |
| pet   | 28.19  | 12.46 | 30.48 |
| gas   | 45.96  | 7.33  | 20.78 |
| mmm   | 2.8    | 1.82  | 2.98  |
| cpr   | 6.06   | 5.11  | 7.54  |
| ppw   | 30.64  | 14.65 | 21.52 |

In the literature, environmental taxes on inputs and commodities vary widely. For instance, carbon taxes designed to achieve specific emission reduction targets have been found to be *Euro*21/*ton* for the EU (Conrad, 2002), \$36/*ton* Bohringer et al. (2001), \$15/*ton* (Adkins, Garbaccio, Ho, Moore and Morgenstern, 2011) or \$10/*ton* (Ho, Morgenstern and Shih,

2008).<sup>8</sup> Other studies define taxes in excess of \$100/ton. These examples are obtained from carbon based studies because the bulk of the literature focuses on carbon taxation. The taxes in Table 4.1 are however based on emissions from the use of intermediate inputs generating four of the six criteria pollutants; Sulfur Dioxide ( $SO_2$ ), Nitrogen Oxides ( $NO_x$ ), Voluntary Organic Matter (VOC) and Particulate Matter (PM10).<sup>9</sup> A common example is chemical fertilizers. In terms of input based taxes, Golombek, Hagem and Hoel (1995) suggest that the production of petroleum, coal and gas should be taxed \$35, \$36 and \$5 per ton of carbon.

To ensure that the emission taxes are robust, I carry out sensitivity analysis by increasing and reducing the abatement efficiency parameter by 33 percent, the resulting simulations replicated the taxes in the baseline equilibrium. In addition, because CGE models are usually considered sensitive to trade parameters, I investigate how the environmental taxes would change in response to a 50 percent rise/reduction in the Armington elasticities of substitution. Here again, taxes in the counter-factual equilibrium equal the baseline values. Finally, I adjust the emission coefficients by  $\pm 20$  percent. the outcome suggests that while taxes are different in both simulations, as would be expected from changes in emission coefficients, the differences in environmental taxes between the regions are the same. Given these results, the environmental taxes outlined in Table 4.1 are robust.

## 4.4 Simulation Design

To answer the research questions, I simulate the effects of revenue neutral per-unit (a) coordinated and (b) harmonized air environmental levies on output, trade and welfare under varying free trade and wage closure assumptions. The coordinated tax is a country-specific tax, while the harmonized tax is based on a three-level tax band. The assumption of free trade involves the removal of, bilateral ad-valorem import and export taxes on all traded goods. This is done by setting the power of export and import taxes to one. I consider

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<sup>8</sup>Ho et al.'s (2008) valuation is based on the US industries.

<sup>9</sup>These are pollutants that pose potential health risks and property damage ([www.epa.gov](http://www.epa.gov)). The other two carbon mooned and lead.

first, the effect of environmental levies when wages for unskilled labor are fixed and second, the effects of these policy shocks when all wages are endogenous. As a departure from standard GTAP closure, global capital goods are assumed exogenous, the Walras slack variable is exogenized to preserve the General Equilibrium (GE) link of the model and the Real Exchange Rate (R) is used as the numeraire.

The benchmark equilibrium includes the input/country specific environmental levies. The counter-factual scenarios are deviations from the baseline optimal levy. Tables 1 and 2 indicate the baseline environmental levies for every dollar spent on the polluting intermediate input.

Letting  $\tau_{opt}$  represent the optimal environmental tax,  $\tau_{LB}$ ,  $\tau_{UB}$  and  $\bar{\tau}_{opt}$  the lower bound, and upper bound and population weighted optimal taxes, equation 4 – 70 specifies the optimal weighted tax and Table 4 – 2 the three simulation shocks.

$$\tau_{opt} = \Phi_{i,r}\tau_{opt,i,r} + \Phi_{i,s}\tau_{opt,i,r} \quad (4-70)$$

Where  $\Phi_{i,r}$  and  $\Phi_{i,s}$  represent population weights for the cooperating regions. I assume the weight for the third region is zero, so that the weighted optimal tax is based on optimal taxes for the regions implementing the policy.

Table 4.2: Description of Shocks

| Coordinated Taxes |               | Harmonized Taxes |                             |
|-------------------|---------------|------------------|-----------------------------|
| Shock             | Description   | Shock            | Description                 |
| $\tau_E = 0$      | Below Optimal | $\tau_{LB}$      | Lower Bound                 |
| $\tau_{opt}$      | Optimal       | $\tau_{WTD}$     | Population Weighted Optimal |
| $\tau_E + \$10$   | Above Optimal | $\tau_{UB}$      | Upper Bound                 |

The assumption of fixed real wage for unskilled labour introduces real wage rigidities into the model. With each shock, unit unskilled labour costs remain constant, allowing substitution towards labour in response to cost increasing shocks, an outcome that potentially

increases welfare.<sup>10</sup> Fixing the real wage allows for the examination of sectoral responses when unit labour costs are constant. For each wage closure assumption, I simulate the effects of harmonized taxes under the assumptions of no free trade and free trade. Free trade involves the bilateral removal of border taxes between the two regulating regions. Table 4.3 below describes the pattern of shocks implemented.

Table 4.3: Counter-factual Experiments

|         | Coordinated   |              | Harmonized       |              |
|---------|---------------|--------------|------------------|--------------|
|         | Levy          | Trade Status | Levy             | Trade Status |
| EXP I   | Below Optimal | No FTA       | Lower Bound      | No FTA       |
| EXP II  | Below Optimal | FTA          | Lower Bound      | FTA          |
| EXP III | Optimal       | No FTA       | Weighted Optimal | No FTA       |
| EXP IV  | Optimal       | FTA          | Weighted Optimal | FTA          |
| EXP V   | Above Optimal | No FTA       | Upper Bound      | No FTA       |
| EXP VI  | Above Optimal |              | Upper Bound      | FTA          |

The results derive from 12 counter-factual experiments; 6 under each wage closure. The following section presents and discusses the simulation results.

## 4.5 Results and Discussion

In the analysis of the changes in output, trade and welfare, I contrast the effects of the two regulatory approaches under the fixed versus the flexible wage closure. Counter-factual results represent deviations from the baseline equilibrium induced by the tax shocks described in the preceding section.

The results are presented in terms of macro aggregates; output, trade, pollution and welfare, and sectoral micro impacts. Changes in output, measured by percentage change in GDP, are examined both on the expenditure and income side. On the expenditure side, GDP is a function of domestic absorption ( $C_{(h)r} + C_{(g)r} + I_r$ ) and net exports  $Q_{(EX)r} - X_{(M)r}$ . Changes in TOT and trade volume represent trade effects of environmental taxes. The

<sup>10</sup>The fixed wage closure is based on the premise that if industries respond to regulatory policy by reducing demand for unskilled labour, then this labour category will bear the brunt of the regulatory burden (Jaffe et al. 1995).

percentage change in TOT is measured by the difference between percentage change in the aggregated price index for exports  $P_{(EX)r}$  and the aggregate price index for imports  $P_{(M)r}$ . The two price indexes are defined by equations 4.65 and 4.66, the regional price indexes are obtained. It follows that changes in TOT are influenced by the regional export price index, import price index, world prices and the real exchange rate. The real exchange rate is assumed to be exogenous, therefore, observed change will be as a result of the three price indexes. The equivalent variations measures the changes in welfare associated with the policy shocks. In the model, I analyze welfare changes in terms of three sources of gains/losses (a) output and employment variations due to changes in production costs, (b) efficiency gains from trade and (c) pollution reduction.

Efficiency changes due to trade occur because the removal of border taxes reduces costs of production. However, in the presence of regulation welfare gains are not guaranteed because the net effect also depends on the strength of the direct output effect or the sensitivity of output to regulatory action. The net output effect is also influenced by the relationship between capital and the related input. In addition, if the import composition of the regulated good is higher, opening up free trade can improve the welfare of the importing country, as demand for the domestically supplied polluting good reduces.

#### **4.5.1 Effects of Environmental Taxes in the Presence of Real Wage Rigidities**

In this section, I consider effects of coordinated and harmonized taxes when the real wage for unskilled labor is fixed. The assumption of real wage unemployment is to account for employment concerns that feature prominently in environmental policy choices. Unemployment is, therefore, voluntary, and the representative household supplies any amount of labor (in work hours) at the given wage. The fixed wage closure makes the simulations in this section intermediate short run to medium term. I begin by comparing the effects of the two policy approaches on output and unemployment, and then I consider trade effects and finally, the welfare implications of the two policy approaches.

## Output Effects

Assuming real wage rigidities, output effects of coordinated environmental taxes between two asymmetric regions competing in perfectly competitive markets (*ASY\_PC*) are tabulated in Table 4.4. Considering first that coordinated taxes are applied without a corresponding removal of trade taxes, results in Table 4.4 suggest that while the EU experiences negligible changes from below optimal and optimal environmental taxes. However, the above optimal tax scheme exerts significant regulatory costs on the region. This is because the stringent tax scenario raises the EU's production costs relative to the baseline. Output falls in part because the incomplete pass-through under perfectly competitive markets implies that the rise in equilibrium output prices cannot offset higher input costs associated with the restrictive policy stance. In this event, firms respond by reducing output or substituting for the relatively lower cost inputs or both. However, because of the assumption of real wage rigidities, the assumed time horizon (intermediate short run to medium run) limits the substitution possibilities. In fact, in the short-medium run capital and intermediates are likely to be complements. For this reason, equilibrium capital and investment fall and consequently domestic absorption declines, hence the 1.4 percent contraction in GDP.

If instead, border taxes are removed, results in Table 4.4 suggest that efficiency gains from free trade reduce the region's regulatory burden significantly. Case in point, the 1.4 percent reduction in output from the above optimal environmental tax scheme in the absence of free trade is completely offset by gains from free trade. This is in part due to the sensitivity of the region's exports to the changes in terms of trade and the relatively high initial baseline border taxes prior to free trade. The same logic explains the significant 2.4 percent rise in aggregate output when environmental taxes are zero.

In contrast, Canada experiences favourable effects from positive environmental taxes under the no free trade assumption. The region's output is 3 percent higher than the baseline under the above optimal scheme. Output is higher despite the stringent regulatory stance because of the likely high substitutability between capital and the polluting intermediate input. Output expands because of the increased demand for capital and the consequent

rise in investment. The same logic explains why the region's output falls by 1.8 percent when environmental taxes are removed. Nevertheless, free trade has negative effects on the region; output falls by 2.4, 0.2 and 0.1 percent under the below, optimal and above optimal schemes. While the 0.1 percent fall in output is minor, it is a significant change from the 3 percent rise in the absence of free trade. Free trade has adverse effects on Canada's regulatory outcomes because compared to the EU, the cost benefits of the removal of trade taxes are lower. Initial trade taxes are much higher in the EU; therefore, the removal of trade taxes confers relative cost advantages on the EU.

Table 4.4: Output Effects under the Fixed Wage Closure (% Change)

| Region | Coordinated Taxes |                 |        |      | Harmonized Taxes |        |      |
|--------|-------------------|-----------------|--------|------|------------------|--------|------|
|        | Initial           | New             | No FTA | FTA  | New              | No FTA | FTA  |
| Canada | $\tau_{opt}$      | $\tau_E = 0$    | -1.8   | -2.4 | $\tau_{LB}$      | 0.7    | -1.1 |
| EU     | $\tau_{opt}$      | $\tau_E = 0$    | -0.1   | 2.4  | $\tau_{LB}$      | -3.0   | 0.2  |
| ROW    | $\tau_{opt}$      | 0.0             | 0.4    | -0.2 | 0.0              | -2.2   | 0.3  |
| Canada | $\tau_{opt}$      | $\tau_{opt}$    | 0.1    | 0.0  | $\tau_{WTD}$     | -0.2   | -0.4 |
| EU     | $\tau_{opt}$      | $\tau_{opt}$    | 0.0    | 0.0  | $\tau_{WTD}$     | -4.3   | 0.3  |
| ROW    | $\tau_{opt}$      | 0.0             | 0.0    | -0.1 | 0.0              | 1.3    | 0.9  |
| Canada | $\tau_{opt}$      | $\tau_E + \$10$ | 3.0    | -0.1 | $\tau_{UB}$      | 5.3    | 0.5  |
| EU     | $\tau_{opt}$      | $\tau_E + \$10$ | -1.4   | -0.6 | $\tau_{UB}$      | -5.1   | -2.2 |
| ROW    | $\tau_{opt}$      | 0.0             | -0.2   | -0.1 | 0.0              | 3.0    | 3.0  |

If instead, environmental taxes are harmonized, the last two columns of Table 4.4 indicate that output effects are stronger in the absence of free trade. Further, the EU experiences the most significant losses. In fact, losses for the region are significantly higher under the harmonized scheme compared to the alternative regulatory approach. According to Table 4, output falls by 3, 4.3 and 5.1 percent under the lower bound, weighted optimal and upper bound environmental tax schemes. The EU's regulatory are high under the harmonized scheme because harmonizing with Canada puts the region at a relative cost ad-

vantage. Canada's baseline optimal taxes are significantly higher than the EU. For instance, table 4-1 show that Canada's baseline petroleum tax is \$28 compared to \$12 in the EU. A minimum harmonized scheme thus reduces Canada's regulatory taxes by \$16. Moreover, the populated weighted optimal tax is skewed towards the lower EU taxes. In the case of the upper bound tax, the EU's polluting intermediates are over internalized. Efficiency gains from free trade offset the region's output losses under all three harmonized tax schemes.

The fall in output is consistent with Roland-Holst and Bussolo (2002) who find environmental taxes applied the absence of free trade to have negative output effects. This fall in aggregate output might also reflect the complementarity between capital and the regulated inputs are complements in the intermediate-short run. If this is the case, then the significant fall in output implies that the cost induced reduction in output is reinforced by a contraction in equilibrium capital and investment. Heutel and Fullerton (2007) give a different perspective. They assert that if capital and labour are highly complementary, a corrective tax on a polluting intermediate input is lowers the return of the factor that is most substitutable with the regulated input. A number of studies, however, find capital to be complementary to intermediate inputs in the short run.

For Canada, the cost advantage of harmonizing with the EU results in higher output relative to the baseline. The most significant gain occurs when harmonized environmental taxes are above optimal. These results are consistent with Cheikbossian's (2010) theoretical proposition that harmonized environmental taxes between asymmetric regions result in gains for the smaller region. It is worth mentioning that Cheikbossian's (2010) contention applies to imperfect competition. When the harmonized scheme is combined with free trade, Canada's regulatory responses are negligible. However, under the weighted tax scheme, free trade results in an output contraction of 0.3 percent compared to the 0.5 percent gain in the absence of free trade. Similarly, the 5.3 percent output gain from an upper bound tax under the no free trade scenario reduces to 0.5 percent. In this case, efficiency gains from free trade do not improve regulatory outcomes.

#### 4.5.2 Trade Effects in the Presence of Real Wage Rigidities

In this section, I discuss the trade effects of environmental tax coordination and harmonization when the labour market is characterized by real wage rigidities. Specifically, I consider the effects of regulatory policy on net exports and the composition of trade. Because of the Armington assumption that traded goods are differentiated by region. I limit my discussion on comparative advantage to changes in relative prices and sectoral shifts.

The results indicate a sharp contrast between changes in net exports in the absence and the presence of free trade. The significantly different results under the two trade scenarios suggest that net exports are not sensitive of changes in regulatory choices. A result consistent with earlier findings by Elliot and Cole (2003), Harris et al. (2002) and van Beers and van den Berg (1997). Considering the EU, its net exports fall by \$3 million in response to above optimal taxes under the no free trade scenario, but rise by \$199 million when border taxes are zero. While the \$199 million is small in relative terms, the distinction shows the region's exports are more sensitive to border taxes. If these observations are linked to changes in output discussed in the preceding section, Turunen-Red and Woodland's (2004) contention that free trade can improve regulatory outcomes provided trade flows are sensitive to free trade is clearly illustrated. More importantly, the EU's net exports are positive when coordinated environmental taxes are combined with free trade. As explained in the previous section, the EU's baseline border taxes are higher relative to Canada, therefore, the removal of border taxes results in sizable gains in cost advantages relative to its trading partner.

Likewise, changes in Canada's net exports are significantly lower when coordinated taxes are applied in the absence of free trade compared to free trade. However, because the region's baseline trade taxes are low, the bilateral removal of trade taxes puts the region at a cost disadvantage. For this reason, Canada's net exports fall. Results in table 4.4B suggest that aggregate trade changes under the free trade scenario follow a similar pattern. Perhaps at this point it is worth qualifying Turunen-Red and Woodland's (2004) contention. The improvement in the trade flows resulting from a policy combining environmental regulation and free trade also depends on the relative size of the border tax reduction.

The observed distinction between trade effects in the absence and presence of free trade lends support to Cole and Elliot(2003), Harris et al.(2001), van Beers and van den Berg(1992), and Tobey (1990) who find that trade flows are not sensitive to regulatory stringency. It is worth noting that their conclusions derive from partial equilibrium and econometric models. Further, like van Beers and van den Berg (1992), results suggest that sectoral trade flows are more sensitive to regulatory choices, particularly in the non energy sectors. Sectoral trade flows are more sensitive to regulatory shocks because the elasticity of aggregate trade flows is lower than that of sectoral flows. The sectoral shifts also indicate that Canada loses comparative advantage in key sectors in the manufacturing and agriculture sectors. An observation that confirms Babool and Reed (2010) who find a negative relationship between manufacturing and policy stringency. However, while my results confirm positive effects of regulatory taxes in the pulp and paper sector observed by Babool and Reed (2010), the gains are negligible.

### 4.5.3 Welfare Effects in the Presence of Real Wage Rigidities

This section discusses welfare implications of coordinated and harmonized environmental taxes on polluting intermediate inputs. Net welfare changes in an externality distorted open economy constitute three effects: (a) the output effect, which captures net changes in aggregate income, (b) the pollution effect and (c) the trade effect. Welfare is measured by the Equivalent Variation (EV). To facilitate comparisons, I have calculated percentage welfare changes using the EV and initial aggregate income.

$$ev_r = \frac{Y_{(EV)r} - Y(o)r}{Y(o)r} \quad (4-71)$$

Figures 4.3 and 4.4 contrast welfare changes under the no free trade and free trade assumptions respectively. The lower panel of each figure illustrates changes in welfare resulting from coordinated environmental taxes, while the upper panel displays the welfare effects of harmonized environmental taxes. A contrast between the lower and upper panel reveals that welfare effects are more pronounced under the harmonized environmental tax scheme.

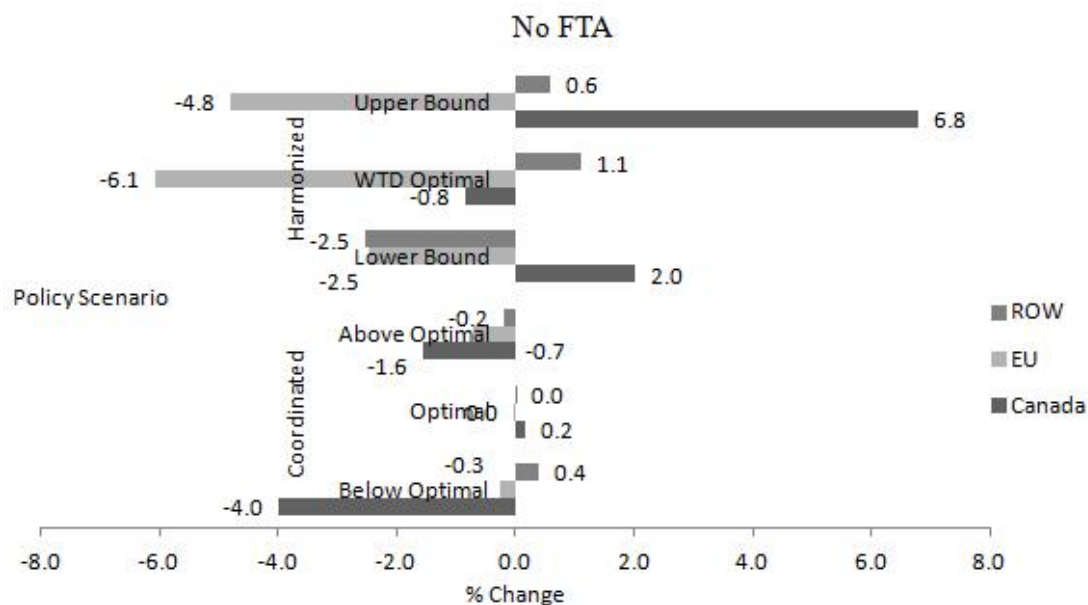
Considering coordinated environmental taxes, welfare effects from coordinated taxes applied in the absence of free trade range from  $-4.8$  percent to  $6.8$  percent, EU for instance, experiences losses under all policy scenarios. The EU's welfare change from an optimal scheme is negligible. However, the region's welfare falls by  $1.4$  percent under the above optimal environmental tax scheme. Given that trade flows are not sensitive to changes in environmental taxes, net welfare changes derive mainly from output and pollution effects. Tables 4.5 to 4.8 in appendix 4.A present the pollution effects. According to table 4.5, pollution falls by  $7.9$  percent in response to above optimal taxes. However, the  $1.4$  percent fall in welfare is mainly due to a  $1.4$  percent fall in aggregate output associated with higher production costs and limited substitution possibilities. If instead, border taxes are removed, efficiency gains from free trade offset the loss. Moreover, table 4.4 indicates that when coordinated environmental taxes are combined with free trade, welfare changes are insignificant.

Unlike the EU, Canada's welfare profile is different and perhaps counter-intuitive. For example, the region's welfare falls by  $4$  percent when environmental taxes are zero, but rises by  $0.2$  and  $3.4$  percent when environmental taxes are optimal and above optimal respectively. Welfare loss under the zero tax scheme is the net effect of a  $1.8$  percent fall in aggregate output and a  $34$  percent rise in pollution as reported in table 4.5 of appendix 4.A. Output falls because producers likely respond to lower production costs by reducing the demand for capital and increasing the use of the dirty intermediates. The welfare reduction exceeds change in output because, because the associated welfare loss is reinforced by a  $34$  percent rise in pollution. Likewise, the welfare gain of  $3.4$  percent from a  $3$  percent rise in output under the above optimal scheme is reinforced by  $7.9$  percent fall in pollution.

In contrast, the region's welfare falls when below, optimal and above optimal coordinated taxes are combined with free trade. The welfare loss of  $4.5$  percent from the zero environmental tax cum free trade scenario occurs because the  $2.4$  percent fall in output is reinforced by a  $31.3$  percent rise in pollution. Further, gains from optimal and above optimal taxes are reversed under free trade. Canada loses under free trade because its initial border taxes are significantly lower than the EU and as a consequence, the EU experiences

cost advantages relative to Canada. Free trade results in the loss of comparative advantage in goods from Canada's key sectors like agriculture and manufacturing. Consequently, net exports fall. Further, a Contrast between Tables 4.5 and 4.6 in appendix 4.A reveals that pollution is changes when environmental taxes are positive are larger under free trade compared to the no free trade scenario. In the case of the above optimal environmental taxes, welfare fall is insignificant. However, the stringent regulatory tax reduces pollution by 11.9 percent reduction in pollution. The fall in pollution comes at the expense of a 1 percent fall in aggregate output.

Figure 4.3: Welfare Effects under the Fixed Wage No FTA Closure



Figures 4.3 also reveals that harmonized taxes in the absence of free trade exert significant welfare costs on the EU. Welfare relative to the baseline falls by 2.5, 6.1 and 4.8 percent. These changes correspond to a 3, 6.3 and 5.1 percent contraction in output under the lower bound, weighted optimal and upper bound environmental tax schemes. As mentioned earlier, the adverse output effects occur because the EU harmonizes with a region with significantly higher initial environmental taxes. However, in each case, the welfare loss is partly offset by gains in utility resulting from lower pollution. For instance, a 2.5 percent reduction in welfare under the lower bound scheme is due to a 3 percent loss in aggregate output and a 7 percent fall in pollution. Likewise, the welfare losses under above optimal

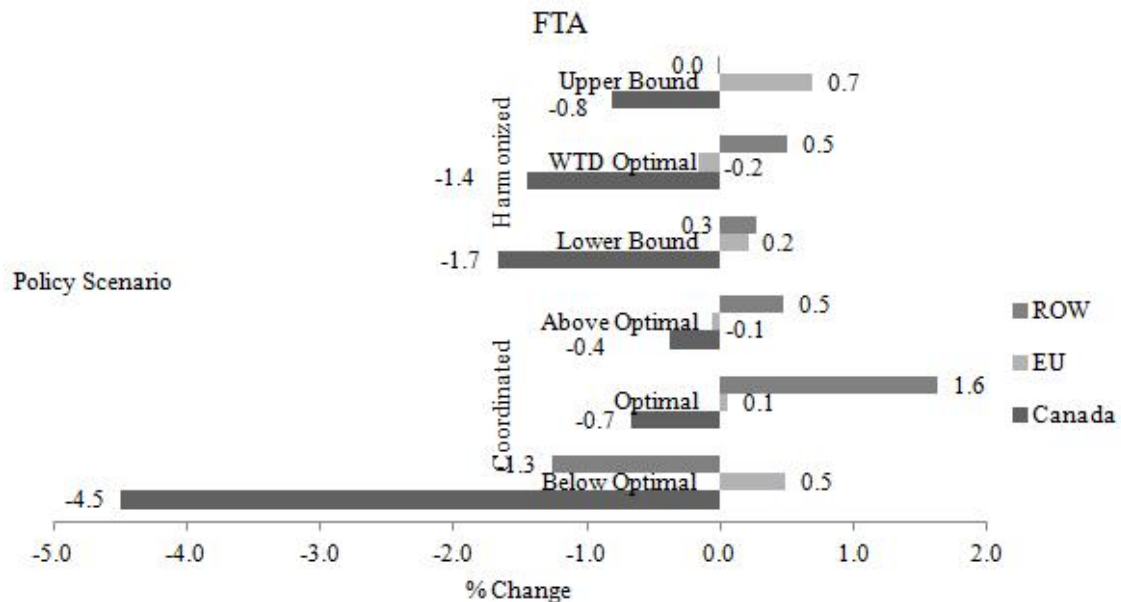
scheme is the net effect of a 5.1 percent fall in aggregate output and a corresponding fall in pollution of 4.3 percent. The 6.1 percent loss in welfare under the weighted optimal scheme derives mainly from a fall in aggregate output because pollution changes by only  $-2.1$  percent. The results here are in contrast to Vlassis (2013) who contends that environmental tax harmonization between asymmetric regions is welfare improving. This result is not surprising because Vlassis (2013) assumes constant prices.

Once the assumption of no free trade is relaxed, the efficiency gains from free trade significantly reduce welfare loss. Under the minimum and upper bound taxes, free trade results in small but positive changes in output. Gallegos (2005) arrives at a similar conclusion; he finds that when the environmental tax is the only policy instrument, a more stringent regulatory tax can be welfare improving. Nonetheless, efficiency the gains from free trade are not strong enough to offset losses from weighted optimal taxes. First, unlike the other two scenarios, combining free trade with the weighted optimal scheme results in a 0.8 percent fall in aggregate output. While small, this result indicates efficiency gains from trade are not strong enough to defray the relatively higher costs or comparative disadvantage of the weighted tax scheme. Likewise, the 0.2 percent reduction in pollution is not high enough to offset the loss in welfare from a 0.8 percent reduction in output. For this reason, welfare falls by 0.2 percent. While insignificant, this is worth discussing because this case demonstrates that free trade does not always improve regulatory outcomes. These observations are in direct contrast to Keen et al. (2002) who posit that a weighted tax scheme based on initial values is welfare improving. Nevertheless, free trade improves the EU's regulatory outcomes because welfare loss of 4.3 percent under the no free trade scenario far exceeds the 0.8 percent loss under the free trade scenario.

In contrast to the EU, Canada's welfare outcomes are better in the absence of free trade. Welfare under the lower and upper bound environmental tax schemes is 2 and 6.8 percent higher than baseline respectively. This result differs from Behrens et al. (2007) who contend that under the assumptions of perfect competition and differing international market size, the smaller region loses from harmonization regardless of the rate of tax. Higher welfare derives from the 0.7 and 5.3 percent rise in output and the 13.6 and 1.5 percent fall

in pollution respectively.

Figure 4.4: Welfare Effects under Fixed Wage FTA Closure



If instead harmonized taxes are combined with the removal of border taxes, figure 4.4 reveals that the policy combination exerts welfare losses on the region. The losses are however below 2 percent. The results also reveal that Canada's welfare losses are slightly higher when taxes are harmonized compared to the coordinated scheme. Further, comparing welfare costs of weighted and upper bound environmental taxes to the optimal and above optimal taxes under the coordinated scheme reveals that the region's losses are 1.4 and 0.8 percent under the harmonized schemes compared to 0.7 and 0.4 percent under the alternative regulatory approach. The higher costs under free trade occur because free trade reduces the region's cost advantages over the EU and causes its net exports to fall. Interestingly, an examination of Table 4.6 in appendix 4.A reveals that the behaviour of pollution differs significantly under the two schemes. In particular, in the presence of free trade, coordinated environmental taxes result in larger pollution reductions compared to harmonized taxes. Moreover, the results suggest that in the presence of real wage rigidities, the relative cost advantages from harmonizing with the EU are reduced under free trade. This result differs from Cheikbossian (2010) because of the restriction on the labour market.

#### 4.5.4 Effects of Environmental Taxes in the Presence of Flexible Wages

In this section, I discuss the effects of joint regulatory policy when wages are fully flexible.

##### Output Effects under Flexible Wage Closure

Table 4-4 displays output effects of coordinated and harmonized taxes under no free trade and free trade assumptions. The results suggest that, in the absence of free trade, output effects of both regulatory approaches are negligible. Under the coordinated environmental taxes, the EU's output falls by 1 percent when the regulatory taxes are zero. While lower output under zero taxes may seem counter-intuitive, the outcome is a likely long-run outcome. In the long run, capital is more substitutable in the long run. Therefore, a fall in the user cost of intermediates induces firms to substitute capital for the relatively cheaper intermediates. The consequent fall in investment reduces aggregate output. The same logic explains why the EU's output is higher than the baseline under the optimal scheme. Now, compared to output outcomes under the fixed-wage assumption, regulatory costs are significantly lower under flexible wages. Under flexible wages, the adjustment through wages absorbs part of the regulatory pulse. Under the free trade assumption, regulatory costs are insignificant; changes in the EU's output are all below 1 percent. However, free trade does not significantly improve regulatory outcomes.

In contrast, Canada's output relative to the baseline is 1.4 percent higher when above optimal tax no free trade scheme. Results indicate both equilibrium capital and unskilled labour employment increase. The rise in the use of primary inputs suggests that firms respond to higher input costs by mainly substituting relatively cheaper capital and unskilled labour for the higher cost intermediates. A likely scenario given that in the long run, firms can easily substitute between inputs. Nevertheless, output falls by 1.5 percent when trade is liberalized because the bilateral removal of tariffs confers sizable cost benefits to EU firms compared to Canada. In addition, net exports fall as the key sectors like manufacturing experience losses in comparative advantage. Table 4-5 suggests that while output effects

of below optimal and optimal taxes are negligible in the absence of free trade, free trade reduces output by 3.5 and 3.1 percent. In all three cases combining coordinated taxes with free trade when wage are flexible results in sizable regulatory costs for the region.

Table 4.5: Output Effects under the Flexible Wage Closure (% Change)

| Region | Initial      | Coordinated Taxes |        |      | Harmonized Taxes |        |      |
|--------|--------------|-------------------|--------|------|------------------|--------|------|
|        |              | New               | NO FTA | FTA  | New              | NO FTA | FTA  |
| Canada | $\tau_{opt}$ | $\tau_E = 0$      | 0.2    | -3.5 | $\tau_{LB}$      | 1.5    | 0.6  |
| EU     | $\tau_{opt}$ | $\tau_E = 0$      | -0.8   | -0.5 | $\tau_{LB}$      | -0.7   | -0.1 |
| ROW    | $\tau_{opt}$ | 0.0               | 0.3    | 0.3  | 0.0              | 0.2    | 0.0  |
| Canada | $\tau_{opt}$ | $\tau_{opt}$      | -1.0   | -3.1 | $\tau_{WTD}$     | -0.5   | 1.0  |
| EU     | $\tau_{opt}$ | $\tau_{opt}$      | 0.6    | 0.0  | $\tau_{WTD}$     | -0.3   | 0.0  |
| ROW    | $\tau_{opt}$ | 0.0               | -0.2   | 0.1  | 0.0              | 0.1    | 0.0  |
| Canada | $\tau_{opt}$ | $\tau_E + \$10$   | 1.4    | -1.5 | $\tau_{UB}$      | -0.1   | 0.1  |
| EU     | $\tau_{opt}$ | $\tau_E + \$10$   | 0.0    | 0.0  | $\tau_{UB}$      | 0.2    | -0.3 |
| ROW    | $\tau_{opt}$ | 0.0               | 0.0    | 0.0  | 0.0              | -0.1   | 0.1  |

If instead, Canada and the EU decide to harmonize environmental taxes, Table 4-5 shows the that only minimum harmonized taxes result is noticeable output changes. In the absence of free trade, the minimum tax scheme reduces the EU's output by 0.8 percent relative to the baseline. The EU's regulatory costs are significantly lower when wages are flexible. For instance, under the minimum environmental tax scheme, the EU's output is only 0.8 percent lower than the baseline compared to 3 percent fall when the real wage for the unskilled labour category is fixed. Likewise, the output effects from the above optimal schemes is significantly below zero percent under the flexible wage closure. In contrast, output falls by 5.1 percent under the fixed-wage closure.

In comparison, Canada's output is 1.5 percent higher. The higher output derives from relatively lower production costs associated with the minimum harmonized taxes. Free trade removes this advantage; the results show that output falls 3.7 percent below the baseline

level. Canada's internal market is considerably smaller than the EU's. For this reason, the EU derives the most benefits from free trade. In general, output changes in both Canada and the EU are negligible, a result consistent with Beghin et al. (2002) who finds growth effects from environmental tax cum free trade policies to be minor. It is worth mentioning that while output effects of weighted optimal and upper bound taxes in the absence of free trade are minor, the negative changes for Canada are consistent with Behrens et al. (2007). In essence, Behrens et al. posit that when markets are perfectly competitive, the smaller region always loses from a harmonized tax scheme. Nevertheless, my analysis differs from the authors because they consider discuss capital tax harmonization.

#### **4.5.5 Trade Effects under Flexible Wage Closure**

This section analyzes the effects of coordinated and harmonized taxes when wages are flexible. The results suggest that trade flows when wages are flexible are slightly more responsive regulatory changes than under the fixed-wage closure. Even the unregulated region (ROW) experiences modest changes in its net exports. Nevertheless, the trade flows are more sensitive to changes in border taxes. Unlike the fixed wage case, the EU experiences net export gains under both no free trade and free trade scenarios. The main difference is that the gains associated with free trade cum regulatory tax policy are significantly larger.

Contrast between trade effects of coordinated and harmonized taxes reveals that compared to the coordinated scheme, the harmonized scheme tends to affect the ROW more. But, because the ROW is not the subject of discussion in this thesis, I will limit my analysis to the two regulated regions. In terms of sectoral shifts, sectoral shifts in the absence of free trade are minor. Comparing sectoral exports and output reveals that in the case of Canada, the petroleum, gas and manufacturing sectors are particularly sensitive to regulatory changes. Under free trade, output and net exports in the petroleum sector fall. This contraction indicates that the changes in relative prices from combining regulatory taxes with free trade tend to shift comparative advantage away from Canada. Likewise, the manufacturing sector's net exports fall even when there are no changes in production. Moreover,

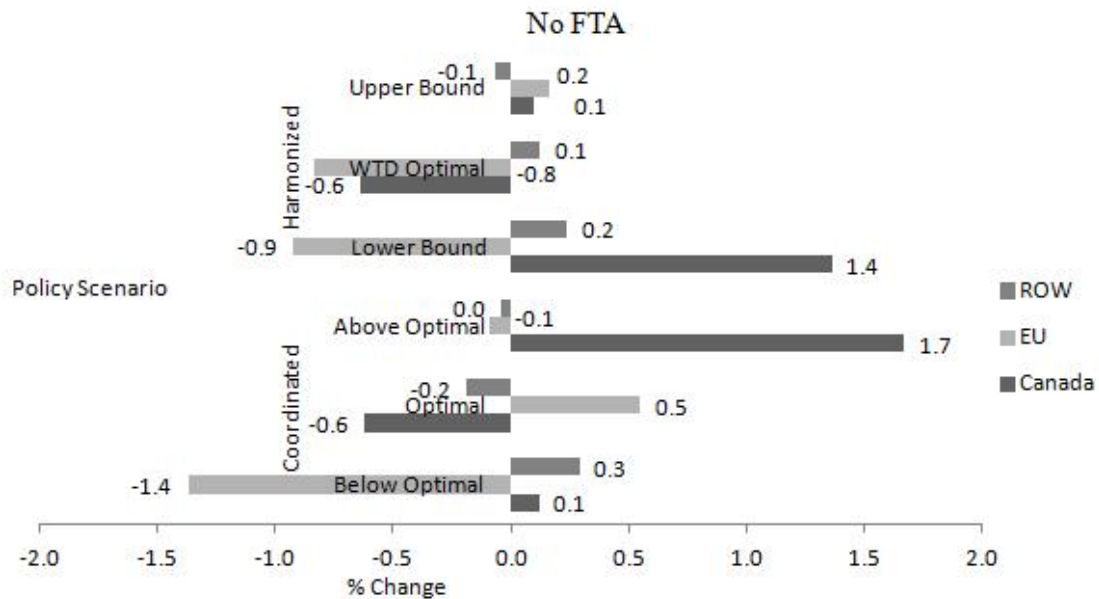
results suggest that the relative price disadvantage from free trade crowds out Canada's comparative advantage. On the other hand, EU agricultural costs relative to Canada fall when regulatory policies are combined with free trade. Results indicate that the regions net exports of agriculture and food rise. However, despite the large import content in the EU's coal supply, coal is the most sensitive to regulatory choices.

Overall, three main insights emerge from the trade effects of collective policies between Canada and the EU. First, aggregate trade flows are not very sensitive to regulatory changes. In fact, trade flows are sensitive to changes in border taxes. Second, sectoral exports are sensitive to regulatory choices. Finally, petroleum, gas, agriculture and manufacturing are the most sensitive to regulatory choices.

#### **4.5.6 Welfare Effects under the Flexible Wage Closure**

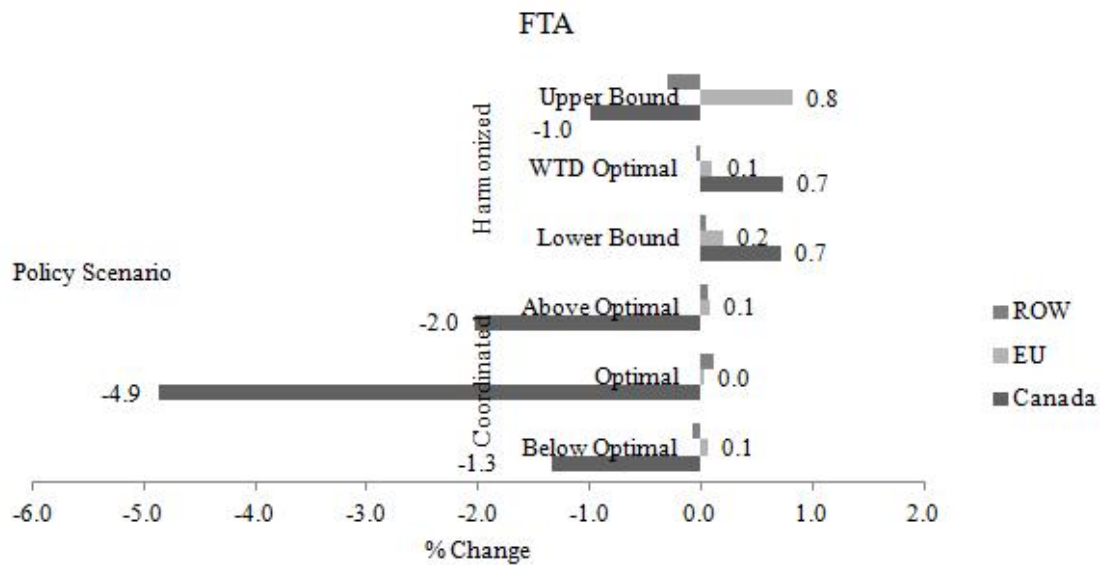
This section discusses welfare effects when wages are fully flexible. Compared to the fixed wage case, welfare effects of harmonized policies applied independent of free trade are flexible are less pronounced. For instance, welfare changes range from range from  $-1.4$  to  $1.7$  percent under flexible wages compared to  $-6.1$  to  $6.8$  percent under the fixed-wage closure. However, while effects differ considerably under free trade, it is difficult to ascertain which of the two scenarios results in higher welfare costs. This is because the results suggest that when wages are flexible, welfare effects range from  $-4.8$  to  $0.8$  percent compared to  $-4.0$  to  $1.6$  percent under the alternative wage closure. Pollution changes under flexible wages are reported in Tables 4.8 and 4.9 in appendix 4.A. Unlike pollution changes under real wage rigidities, pollution changes when wages are flexible are stronger when taxes are harmonized compared to coordinated. This is an important result because it suggests that when an economy is characterized by involuntary unemployment, coordinated taxes are more effective at reducing polluting. If however the economy is at full employment, harmonized taxes are more effective.

Figure 4.5: Welfare Effects under Flexible Wage No FTA Closure



Coordinated positive environmental taxes in the presence of free trade, result in minor welfare changes for the EU. For example, welfare improves by 0.5 percent when the taxes are optimal, but worsens by 0.6 percent under the more restrictive above optimal environmental taxes scheme. Nevertheless, Figure 4.5 shows that the removal of optimal environmental taxes reduces welfare by 1.4 percent. This outcome is the net result of a 0.8 percent reduction in aggregate output and 13.5 percent rise in pollution. While logic would dictate that output rises when production costs fall, in a general equilibrium the net effect on output is also influenced by the degree of substitution between inputs. Negligible output effects also occur when trade is liberalized. In fact, the efficiency gains from trade more than offset the 1.6 percent loss when taxes are zero. The preceding results, therefore, suggest that when the EU competes with Canada in perfectly competitive international markets, free trade improves the EU's regulatory mutes or improves the region's regulatory effects provided wages are flexible.

Figure 4.6: Welfare Effects under Flexible Wage No FTA Closure



In contrast, Canada's welfare outcomes when wages are flexible are mixed. For instance, when environmental taxes are coordinated, the region experiences a negligible loss in welfare (0.6 percent) under the optimal scheme, and a gain of 1.7 when regulatory taxes are above optimal. In the case of the optimal environmental tax scheme, the 0.6 percent fall in welfare occurs despite the 3.3 percent fall in pollution because aggregate output falls by 1 percent. Likewise, when regulatory taxes are above optimal, the welfare gain from a 1.4 percent rise in aggregate income is reinforced by an 11 percent fall in pollution, hence the welfare gain of 1.7 percent. Unlike the EU, Canada's regulatory responses under free trade are significantly larger. In fact, the region's welfare losses from coordinated environmental taxes range from 4 to 2 percent. Comparing Figures 4.5 and 4.6 reveals that Canada's losses are more pronounced under free trade. First, the region loses from the optimal taxes under the free trade assumption amount to 4.9 percent compared to 0.6 percent under the same policy in the absence of trade. Likewise, welfare falls by 2 percent when above optimal taxes are combined with free trade compared with the gain of 1.7 percent the when regulatory scheme is implemented independent of free trade. Again, free trade results in losses in comparative advantage in the region's key sectors like manufacturing. Not only that, net exports fall when trade taxes are removed. Hence, unlike the no free trade result, the trade effect also affects net welfare outcomes. Further, as indicated in Tables 4.8 and 4.9, pollution effects

rise under free trade.

Now, if environmental taxes are harmonized, welfare effects are more favourable compared to coordinated scheme. First, considering changes in the EU in the absence of free trade, Figure 4.5 demonstrates that the region's experiences minor losses in welfare all below 1 percent. Similarly, welfare changes under free trade are positive but insignificant. The negligible welfare changes are expected given that the flexible wage scenario is a long run scenario. Pollution changes under the no FTA scenario are 3.4, 10.9 and -3.8 percent under the minimum, weighted and upper bound environmental tax schemes respectively. In contrast, pollution changes from the three schemes in the presence of free trade are 1.6, -1.6 and 1.5 percent. Interestingly, pollution changes under free trade are smaller.

Welfare effects for Canada differ in comparison to its trading partner. First, an examination of Tables 4.8 and 4.9 indicates that pollution changes are higher under free trade compared to the no free trade scenario. For instance, in the absence of free trade, pollution changes by 9.3, -14.9 and -3.1 percent under minimum, weighted optimal and upper bound environmental taxes. In contrast, pollution changes by 1.6, -1.6 and 1.5 when the three harmonized schemes are combined with free trade. In terms of welfare, changes in the absence of free trade are larger. For example, under the minimum environmental tax scheme, welfare rises by 1.4 percent due in a 1.5 percent rise in output and an offsetting 14.9 percent rise in pollution. The same scheme under free trade raises welfare by only 0.2 percent.

## 4.6 Conclusion

The objectives of this chapter are to quantify and compare the effects of environmental levy coordination and harmonization on output, trade and welfare under standard neoclassical assumptions and to determine the effect of free trade on regulatory outcomes. The results show that under perfect competition, labor market considerations are significant determinants of policy outcomes. In addition, this chapter also shows that regulatory responses

are sensitive to the size of the domestic market. In general, when markets are perfectly competitive free trade improves regulatory responses for the EU. The results for Canada are mixed.

Output effects are stronger in the presence of the real wage rigidities. The analysis shows that in the presence of real wage rigidities, harmonizing taxes without a corresponding reduction in trade taxes has adverse effects of EU's output regardless of the level of the harmonized tax. In essence, the results suggest that the region stands to lose from harmonizing with a higher tax region without the a corresponding reduction in border taxes. In contrast output effects of coordinated effects are negligible. Similarly, Canada's regulatory responses are significant under the harmonized scheme. More importantly, Canada's output effects are sensitive to the relationship between complementarity between capital and regulated goods. Free trade however reduces the output gains and losses from harmonizing with the EU. Further, when markets are competitive, output responses for the EU when wages are endogenous are negligible regardless of the regulatory approach. Conversely, for Canada, output responses are significant when coordinated taxes are combined with free trade.

Aggregate trade responses are consistent with earlier studies that find no significant relationship between aggregate trade and regulatory stringency. In contrast, sectoral flows are more sensitive. In particular, the results support earlier observations that trade flows in non energy sectors are more responsive to regulatory changes. Further, industrial shifts are observed in the petroleum and coal sectors. Welfare effects are also sensitive to labor market assumptions. The EU experiences sizable losses welfare losses from a harmonized tax cum no free trade policy in the presence of real wage rigidities. The removal of the labor constraint combined with free trade is welfare improving under both regulatory approaches. In the case of Canada, like the EU, free trade is welfare improving when the real wage for the unskilled labor category is fixed. For both regions, this result is in contrast to Hoel (1997).

The results in this section demonstrate that when commodity markets are perfectly competitive, regulatory costs are sensitive to labour market considerations. Losses for the

EU are higher in the presence of real wage rigidities. In contrast, Canada's regulatory costs are higher when free trade is combined with coordinated taxes under the flexible wage closure. The next chapter relaxes the assumption of perfect competition.

## Appendix 4-1

Table 4.6: Pollution Effects under the Fixed Wage Closure: No FTA

| Region | Coordinated Scheme |              |                     | Harmonized Scheme |              |              |
|--------|--------------------|--------------|---------------------|-------------------|--------------|--------------|
|        | $\tau_{opt} = 0$   | $\tau_{opt}$ | $\tau_{opt} + \$10$ | $\tau_{LB}$       | $\tau_{WTD}$ | $\tau_{WTD}$ |
| Canada | 34.4               | -1.6         | -6.9                | -13.6             | 16.8         | -1.5         |
| EU     | 8.5                | 0.6          | -7.9                | -7.0              | -2.1         | -4.3         |
| ROW    | 8.9                | 8.1          | 8.0                 | 9.3               | 8.1          | 9.7          |

Table 4.7: Pollution Effects under the Fixed Wage Closure: FTA

| Region | Coordinated Scheme |              |                     | Harmonized Scheme |              |             |
|--------|--------------------|--------------|---------------------|-------------------|--------------|-------------|
|        | $\tau_{opt} = 0$   | $\tau_{opt}$ | $\tau_{opt} + \$10$ | $\tau_{LB}$       | $\tau_{WTD}$ | $\tau_{LB}$ |
| Canada | 31.3               | -14.7        | -11.9               | 16.7              | 7.9          | -0.3        |
| EU     | 15.6               | 0.7          | -6.5                | -1.3              | -0.2         | -2.5        |
| ROW    | 8.3                | 8.5          | 8.1                 | 8.4               | 8.1          | 8.3         |

Table 4.8: Pollution Effects under Flexible Wages: No FTA

|        | Coordinated Scheme |              |                     | Harmonized Scheme |              |             |
|--------|--------------------|--------------|---------------------|-------------------|--------------|-------------|
|        | $\tau_{opt} = 0$   | $\tau_{opt}$ | $\tau_{opt} + \$10$ | $\tau_{LB}$       | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 13.1               | -3.3         | -11.0               | 9.3               | -14.9        | -4.8        |
| EU     | 13.5               | 0.5          | -5.2                | 3.4               | 10.9         | -2.1        |
| ROW    | 8.1                | 8.1          | 8.1                 | 8.0               | 8.1          | 7.5         |

Table 4.9: Pollution Effects under Flexible Wages: FTA

|        | Coordinated Scheme |              |                     | Harmonized Scheme |              |             |
|--------|--------------------|--------------|---------------------|-------------------|--------------|-------------|
|        | $\tau_{opt} = 0$   | $\tau_{opt}$ | $\tau_{opt} + \$10$ | $\tau_{LB}$       | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 13.1               | 16.8         | 31.2                | 36.8              | 14.5         | -3.3        |
| EU     | 13.5               | -2.0         | -32.9               | 1.6               | -1.6         | 1.5         |
| ROW    | 8.1                | 8.1          | 8.1                 | 8.7               | 7.9          | 7.8         |

Table 4.10: Model Variables

| Quantity Variables | Description              | Prices      | Description                      |
|--------------------|--------------------------|-------------|----------------------------------|
| $Q$                | Gross output             | $P$         | Gross output price composite     |
| $Q_{(va)}$         | Value Added              | $P_{(va)}$  | Value added composite price      |
| $Q_{i,j,r}$        | Intermediate composite   | $P_{i,j,r}$ | Composite intermediate price     |
| $C$                | Costs                    | $P_{(NK)}$  | Composite capita- resource price |
| $K$                | Capital                  | $P_{(K)}$   | Price of capital                 |
| $L$                | Labor composite          | $\bar{W}$   | Average sectoral wage            |
| $N$                | Resources                | $P_{(N)}$   | Price of resource input          |
| $L_{(skl)}$        | Skilled                  | $W_{(skl)}$ | Real wage for skilled labor      |
| $L_{(ul)}$         | Unskilled labor          | $W_{(ul)}$  | Real Wage for unskilled labor    |
| $X_{(arm)}$        | Armington composite      | $P_{(arm)}$ | Armington composite price        |
| $X_{(M)}$          | Imports                  | $P_{(M)}$   | Price of imports                 |
| $Q_{(EX)}$         | Exports                  | $P_{(EX)}$  | Price of exports                 |
| $Q_{(v)}$          | Dirty intermediate Input | $P_{(v)}$   | Price of dirty intermediates     |
| $E$                | Emissions                | $\tau_E$    | Second best E-tax                |
| $U$                | Per-capita utility       | $P_{(pol)}$ | Shadow price of pollution        |
| $Q_{(DS)}$         | Domestic Supply          | $P_{(hD)}$  | Private HH price vector          |
| $Z$                | Pollution damages        | $P_{(gD)}$  | Government price vector          |
| $S$                | Savings                  | $P_s$       | Price of savings                 |
| $U_g$              | Government utility       | $P_{(cet)}$ | CET price                        |
| $U_h$              | Private HH utility       | $P_{(K)}$   | Rent of rate of capital          |
| $Y$                | Income                   | $W_N$       | Rental rate of resources         |
| $T$                | Transfer payments        | $R$         | Real exchange rate               |

Table 4.11: Model Parameters

| Parameter      | Description                    | Parameter     | Description                  |
|----------------|--------------------------------|---------------|------------------------------|
| $\alpha$       | Share parameters               | $\beta$       | Cobb Douglas share           |
| $\rho$         | Substitution parameter         | $\phi$        | Disutility from pollution    |
| $\sigma$       | Elasticity of substitution     | $\Omega$      | Pollution conversion factor  |
| $\alpha_{arm}$ | Armington share parameter      | $\vartheta$   | CDE expansion parameter      |
| $\rho_{arm}$   | Armington parameter            | $B$           | CDE distribution parameter   |
| $\sigma_{arm}$ | Armington elasticity           | $\rho_{cet}$  | CDE substitution parameter   |
| $\sigma_{cet}$ | Elasticity of transformation   | $\rho_{cet}$  | Elasticity of transformation |
| $\lambda$      | Frisch parameter               | $\chi$        | Flexibility parameter        |
| $\theta$       | Marginal Cost of Public Funds  | $\omega$      | Population weights           |
| $\psi$         | Emission coefficient           | $\alpha_{ef}$ | Abatement expenditure share  |
| $\gamma$       | Abatement efficiency parameter |               |                              |

# Chapter 5

## ENVIRONMENTAL POLICY COOPERATION AND TRADE

### The Case of Asymmetric Regions and Imperfect Competition

*“the list is short as the work is hard”*

Antweiler and Trefler

#### 5.1 Introduction

In this chapter, I use a CGE model to assess the effects of environmental policy coordination and harmonization in the presence of imperfectly competitive commodity markets and Increasing Returns to Scale (IRTS). The objective is to ascertain whether policy outcomes are sensitive to market structure, examine the validity of strategic policy incentives and explore how free trade affects regulatory policy outcomes when asymmetric regions compete in imperfect markets. To achieve this, I simulate the effects of the two regulatory approaches on output, market structure, competitiveness and welfare under (a) free trade and no free trade scenarios and (b) endogenous wage and fixed wage scenarios.

The questions addressed here are particularly relevant because the presence of imperfect competition and increasing returns to scale introduces an added distortion to an economy; underproduction due to market power. This is because by restricting output, firms can increase prices and revenue. The prices, therefore, do not reflect the opportunity cost of production. Theoretically, the outcome of regulatory policy in such cases can be ambiguous. For instance, an emission tax while reducing pollution, can have a negative welfare effect because firms respond to cost, and price increases by cutting the output of an already under-produced commodity leaving consumers worse off.

More importantly, in practice, imperfect competition is a common feature of international commodity markets. In particular, the bulk of global trade is characterized by (a) two-way trade in similar commodities, (b) the dominance of a few firms and (c) the existence of substantial economies of scale, especially in manufacturing. Policy shocks are bound to have different effects compared to the perfectly competitive case. Hertel and Roland-Holst (1997) contend that same policy instrument applied under perfect competition can have disparate effects under imperfect competition. This possibility warrants a separate analysis of policy implications within the context of realistic market considerations. Moreover, the presence of economies of scale and imperfect competition implies that markets can only support a few firms. As a consequence, there are potential gains from high profits and economic rent.<sup>1</sup> The existence of substantial rents can cultivate incentives for governments to manipulate trade in order to increase market share, harness rents or improve Terms of Trade (TOT). Trade flows can be manipulated directly via trade policy or indirectly through environmental policy. In the absence of trade policy tools, governments can potentially use the environmental policy as a strategic tool.

The literature on environmental policy cooperation and strategic incentives is extensive. However, it is predominantly theoretical, and the results inconclusive. Specifically, two competing positions exist; first, rent-shifting motives can cause governments to set less than optimal regulatory targets in order to capture market share and shift rents to domestic firms. Second, an opposite but equally likely view suggests that governments can set above optimal targets (over internalize externalities) in order to shift the regulatory burden to foreign consumers and capture surplus. The former, suggested by Brander and Spencer (1985), Kennedy (1994), Barrett (1994) and Ulph (2001) constitutes the deliberate worsening of TOT. The latter, advanced by Markusen (1975) and Duval and Hamilton (2004) involves the improvement of TOT. Furthermore, divergent views about the effects of policy on market structure suggest that regulation can have pro-competitive effects or lead to deeper concentration (van Long and Soubeyran, 2005). The uneven application of taxes even when policies are coordinated raises competitiveness concerns.

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<sup>1</sup>Economic rent is the sum of the change in profits resulting from an increase in the flow exports and the increase in export tax revenue (Kennedy, 1994).

The presence of free trade raises the possibility of using environmental policy tools for strategic motives. To circumvent this, trading partners can harmonize environmental policy thereby preserving the competitive structure of the markets. The support for harmonization of environmental policy under imperfect competition arises from concerns that the uneven application of environmental taxes can result in competitiveness losses, especially when capital is mobile. This is because when a trading region applies a relatively higher tax vis a vis its trading partner, relatively higher production costs have the potential of lowering the return to capital. Assuming that wages are endogenous, the consequent fall in capital can have adverse employment effects.

Harmonization of environmental taxes, while inefficient, preserves the competitiveness of firms in international markets, especially under conditions of free trade (formal FTA). Under free trade, the absence of trade policy tools creates incentives for governments to use environmental taxes as strategic policy tools to manipulate market shares and improve competitiveness (Kox and van der Tak, 1996). If countries harmonize environmental taxes to countervail these tendencies, they would still face different total regulatory costs. Because of this, governments may be motivated to manipulate other prices to cushion the regulatory costs. In terms of the relative distribution of the regulatory burden, Cheikbossian (2010) and Behrens et al.(2007) posit that harmonization favors the smaller region. Others like Duval and Hamilton (2004) explain that when asymmetries between regions are derive from the distribution of consumers and marginal external damages, harmonization has superior welfare effects. Likewise, Keen et al. (2002) posit that a weighted harmonized tax scheme based on initial country specific taxes can potentially raise welfare.

Cautious optimism marks coordination of environmental policy. Coordination involves joint regulation that allows trading partners to set country-specific taxes. Unlike harmonized policies, coordinated taxes can be set to equal marginal damages and be efficient. In addition, implementing country-specific taxes gives government the discretion to impose taxes that minimize regulatory costs. Nevertheless, coordinated policies give rise to strategic incentives. In the literature surveyed in chapter 2, the question of environmental policy coordination yields conflicting positions. One strand of literature demonstrates that

policy coordination is unnecessary when pollution is local (Hoel, 1997). In contrast, Kox and van der Tak (1996) assert that even when pollution is local, there is scope for policy coordination. Moreover, when labor market dynamics are considered, coordinated policies have potential welfare benefits. Further, additional distortions introduced by international trade necessitate policy coordination (Hoel, 2005). With regard to the distribution of the regulatory burden between asymmetric regions, Cheikbossian (2010) contends that beyond a minimum tax, policy coordination benefits the smaller region, provided pollution is not purely transboundary.

The interaction between strategic policy and welfare has been extensively explored in the theoretical literature. However, the question of environmental policy harmonization and coordination under imperfect competition has received limited attention in both theoretical and empirical literature. To the best of my knowledge, no study exists that compares the effect of the harmonization and coordination of corrective taxes on intermediates in the presence of imperfect competition. Neither is there a study that examines or compares the effect of free trade on outcomes of the two policy approaches. Furthermore, labor market considerations while important, have not been addressed in the context of the two regulatory approaches. The dearth of empirical studies that quantitatively evaluate policy harmonization and coordination outcomes in the presence of imperfect competition and the ambiguity surrounding cooperation and strategic motives are the motivation for this chapter.

This chapter extends literature on issue linkage in several ways. First, I quantify the effects of coordinated and harmonized emission levies on polluting intermediates when asymmetric bilateral trading partners compete in imperfectly competitive markets. Second, I examine and compare the effects of free trade on regulatory outcomes. Further, I simulate effects of optimal, below and above optimal taxes to establish the empirical validity of rent shifting and burden shifting arguments. This too has received little empirical attention. Finally, I demonstrate how market structure and labor market considerations influence regulatory outcomes.

To achieve this, I simulate the effects of harmonized and coordinated levies using a CGE model that incorporates both market power and emissions generated from the use of intermediate good in production. To preserve the competitive general equilibrium structure, I assume market power arises from firm-level economies of scale, and free entry and exit. The two assumptions ensure that that zero profits prevail in equilibrium. In addition, I link market structure to emission taxes. To examine the pollution and rent shifting motivations, I simulate below optimal, optimal and above optimal policy scenarios. Finally, I compare regulatory policy outcomes when the real wage for the unskilled labor category is fixed to outcomes when the wages are fully flexible.

The chapter is has the following structure: Section 5.2 describes the model extensions. Section 5.3 explains the chapter specific data and calibration. Section 5.4 highlights the application and simulations. Section 5.5 discusses the simulation results under both fixed and flexible wage assumptions. The chapter conclude with section 5.6.

## 5.2 Model Extension

The model is an augmented version of the GTAP model with imperfect competition, Increasing Returns to Scale (IRTS) and endogenous market structure, where firms compete a la Cournot.<sup>2</sup> It consists of three regions, ten oligopolistic sectors and four primary inputs (capital, skilled labour, unskilled labour and resources). I make the following modifications to the standard GTAP model: First, I include emission generated from intermediate input use. Second, I augment intermediate input prices to include corrective second best optimal taxes. Third, I add a fourth level nest describing substitution possibilities between polluting inputs. Finally, I modify the regional household preferences to include disutility from pollution. The latter specification ensures that the welfare measure captures changes in pollution. Further, as a departure from the standard GTAP model, the numeraire is the real exchange rate, and the Armington structure is non-nested. The non-nested Armington

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<sup>2</sup>The Global Trade Analysis Project (GTAP) model developed by the Department of Agricultural Economics at Purdue University

structure implies that domestic and foreign firms compete in one single market. This specification reduces the complexity of calibrating different elasticities for domestic and foreign demand.

In the following sections, indexes “r” and “s” represent regions, where r is the home region and s its trading partners. “i” and “j” represent sectors where  $i \neq j$ , goods from “i” are used as intermediates in the production of “j”. Uppercase letters represent activities, distribution and technology shift factors, while lower case and Greek letters parameters.

### 5.2.1 Production and Supply

Each sector produces a single homogeneous commodity sold in both domestic and foreign markets. Firms compete in domestic and foreign markets by choosing quantities to maximize profits. In addition, firms do not price discriminate, they charge a single price in both domestic and foreign markets. The assumption of endogenous market structure implies that the zero profit condition determines the number of firms; this ensures that in equilibrium price equals average costs. In addition, oligopolistic markups are endogenous. This feature coupled with endogenous firms ensures the existence of a unique solution (Hoffman, 2002).<sup>3</sup>

Producers optimize decisions in two stages. First firms choose a combination of inputs to minimize the cost of producing gross output ( $q_{i,r}$ ) using a CES nested production structure. Second, they maximize profits by choosing quantities to sell in domestic and foreign markets taking competitor quantities as given. Prices are determined by the downward sloping demand curves. Because of the assumption of endogenous market structure and border product differentiation, long run prices equal average costs.

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<sup>3</sup>This is done to overcome Mercenier’s (1995) concerns about the multiplicity of equilibria associated with models of imperfect competition.

## Production

Production is described by a four level nested structure. The top level nest specifies the cost and CES production function that optimizes the cost of producing  $q_{i,r}$ . Increasing returns to scale derive from fixed costs; I assume that firms commit a given amount of resources to abatement and other activities a priori. Letting  $C_{i,r}$ ,  $C_{i,r}^0$ ,  $\bar{C}_{i,r}$  and  $c_{i,r}$  denote total, fixed, average and marginal costs respectively, the top level nest is defined by:

$$C_{i,r} = C_{i,i}^o + (P_{(va)i,r}q_{(va),r} + P_{i,j,r}q_{i,j,r}) \quad (5-1)$$

$$\bar{C}_{i,r} = \left( \frac{C_{i,r}^o}{q_{i,r}} \right) + c_{i,r} \quad (5-2)$$

where  $\bar{C}_{i,r} > 0$  and  $\delta\bar{C}_{i,r} < 0$ . The term in the brackets is the variable component of the total cost also defined as  $C_{i,r}q_{i,r}$ ,  $P_{(va)i,r}q_{(va),r}$  and  $P_{i,j,r}q_{i,j,r}$  are the expenditures on the Value Added (VA) composite factor and the intermediate input composite. Equation 5-2 defines the average cost as a function of the average fixed cost and marginal cost. The restrictions  $\bar{C}_{i,r} > 0$  and  $\delta\bar{C}_{i,r} < 0$  imply that average costs are non-negative and declining. Finally, marginal costs are invariant to output, hence, economies derive solely from fixed costs as depicted in equation 5-2.

Economies are measured by the output elasticity ( $\xi_{i,r} = \frac{\bar{C}_{i,r}}{c_{i,r}}$ ), which measures the percentage change in costs resulting from a 1 percent increase in output.<sup>4</sup> Following François (1997), I use the Cost Disadvantage Ratio (CDR) as a measure of scale economies. The latter is a measure of unrealized economies and is defined as:

$$CDR_{i,r} = \frac{\bar{C}_{i,r} - c_{i,r}}{C_{i,r}} \quad (5-3)$$

Since the underlying CES technology is homothetic, the cost output elasticity is related to the CDR by  $\xi_{i,r} = \frac{1}{1-CDR_{i,r}}$ .

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<sup>4</sup>A value greater than one indicates the presence of economies and vice versa

The firm minimizes total costs (equation 5-1) subject to a CES technology constraint defined by equation (5-4). As a departure from the standard GTAP model, I assume non-zero elasticity of substitution between the value added and the intermediate composite inputs associated with the production with good "i" in region "r".<sup>5</sup> The parameters  $\alpha_{(va)i,r}$  and  $\alpha_{i,j,r}$  represent the share of the each input composite in firm level gross output( $q_{i,r}$ ) in industry "i". The top level substitution parameter,  $\rho_q$  determines the elasticity of substitution  $\sigma_q$  via the equation  $\sigma_q = \frac{1}{1-\rho_q}$ .

$$q_{i,r} = [\alpha_{(va)i,r} q_{(va)i,r}^{\rho_q} + \alpha_{i,j,r} q_{i,j,r}^{\rho_q}]^{1/\rho_q} \quad (5-4)$$

$$q_{(va)i,r} = \alpha_{(va)i,r} \left( \frac{P_{i,r}}{P_{(va)i,r}} \right)^{\sigma_q} q_{i,r} \quad (5-5)$$

$$q_{i,j,r} = \alpha_{i,j,r} \left( \frac{P_{i,r}}{P_{i,j,r}} \right)^{\sigma_q} q_{i,r} \quad (5-6)$$

$$P_{i,r} = [\alpha_{(va)i,r} P_{(va)i,r}^{1-\sigma_q} + \alpha_{i,j,r} P_{i,j,r}^{1-\sigma_q}]^{1/1-\sigma_q} \quad (5-7)$$

For simplicity, most CGE models including GTAP assume that primary and intermediate inputs are perfect complements. However, literature presents conflicting positions regarding the substitutability and complementarity of primary and intermediate inputs. For this reason, the first level cost minimization choices for firms based on a CES production function. By Shepherd's lemma and the envelope theorem, the firm's cost minimization problems results in conditional composite value added and intermediate demands specified by equations 5-4 and 5-5. Intermediate goods are all tradables across regions, while the value added composite constitutes non-tradables. The structure of the value added nest, and its sub-nests is as described in appendix 5-A. The aggregate price for gross output is given by equation 5-7. The existence of market power in the intermediate commodity market implies that intermediate inputs face oligopolistic pricing.

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<sup>5</sup>This specification is important because the level of substitution between inputs is central to determining the extent of policy shock transmissions within sectors.

### 5.2.2 Supply

Firms competing a la Cournot maximize profits given factor and commodity prices and competitor quantities by determining the quantity of gross output ( $q_{i,r}$ ) to sell in domestic and foreign markets. The relationship between domestic and foreign supply is described by the Constant Elasticity of Transformation (CET) function. The CET specification follows the Armington convention where transformability between domestic and foreign sales is imperfect. The gross output is the CET quantity such that  $q_{i,r} = q_{(cet)i,r}$ . Letting  $q_{(ex)i,r}$  and  $q_{(xd)i,r}$  denote each firm's domestic and foreign supply quantities of good  $i$  in region  $r$ , and  $\alpha_{(cet)i,r}$ ,  $\rho_{cet}$  and  $\sigma_{cet}$  the CET share parameter, transformation parameter and the elasticity of transformation, where  $\sigma_{cet} = \frac{1}{1+\rho_{cet}}$ ; the CET supply composite is defined by:

$$q_{(cet)i,r} = [\alpha_{(cet)i,r} q_{(ex)i,r}^{\rho_{cet}} + (1 - \alpha_{(cet)i,r}) q_{(ds)i,r}^{\rho_{cet}}]^{1/\rho_{cet}} \quad (5-8)$$

For ease of calibration, I assume that firms choose their quantities by anticipating or making conjectures about competitor responses. Given that, firms in each sector are symmetric both in domestic and foreign markets, equation 5-11 defines the relationship between firm output and total sectoral output.

$$Q_{i,r} = n q_{i,r} \quad (5-9)$$

$$\Omega_{i,r} = \frac{\delta Q_{i,r}}{\delta q_{i,r}} \quad (5-10)$$

Where  $n$ ,  $Q_{i,r}$  and  $\Omega_{i,r}$  refer to the number of firms in sector  $i$ , the total quantity/CET quantity and the conjectural variation. Given marginal costs  $c_{i,r}$ , the firm maximizes profits given the quantities of competitors in domestic and foreign markets by:

$$\pi_{i,r} = P_{(cet)i,r} q_{(cet)i,r} - C_{i,r}^o - c_{i,r} Q_{i,r} \quad (5-11)$$

where

$$P_{(cet)i,r}q_{(cet)i,r} = (P_{(ex)i,r}q_{(ex)i,r} + P_{(ds)}q_{(ds)i,r}) \quad (5-12)$$

Substitution of 5-14 into the first order conditions yields the following price-cost margins for both domestic and foreign markets:

$$\frac{P_{i,r} - c_{i,r}}{c_{i,r}} = \frac{\Omega_{i,r}}{n_{i,r}|\mu_{i,r}|} \quad (5-13)$$

where  $\mu_{i,r} < -1$

The oligopolist charges a single price in both markets, therefore,  $P_{i,r} = P_{(ex)i,r} = P_{(ds)i,r}$ . Further, each firm charges a single mark-up in both domestic and foreign markets. Equation 15 defines the firm's price cost margin as a function of perceived elasticity  $\mu_{i,r}$ , the number of firms ( $n$ ) and the conjectural variation  $\Omega_{i,r}$ . As per standard Cournot Model, the latter equals unity. The latter restriction ensures that Nash is obtained as equilibrium. Mark-up over marginal cost varies endogenously with elasticity of demand and the number of firms. The number of firms is determined by the zero profit condition. An increase in the number of firms reduces mark-up, similarly an increase in elasticity of demand reduces market concentration. When economies are present, the entry and exit of firms can alter the scale of production, *ceteris paribus*, and consequently alter aggregate efficiency (Francois and Roland-Holst, 1997, p. 341).

The industry elasticity is a linear combination of demand elasticities weighted by market shares. It is calibrated using the Armington elasticity of substitution  $\sigma_{arm}$  and market shares.

$$\eta_i = \sigma_{arm} - (\sigma_{arm} - \Omega_{i,r})\Theta_{i,r} \quad (5-14)$$

Where  $\Omega_{i,r} = 1$  and  $\Theta_{i,r} = \sum \frac{q_{(cet)i,r}}{Q_i}$

The market shares are a weighted combination of the CET composite. In equation

5-16, I assume a non-nested Armington structure; Armington and regional substitution elasticities are equal.

### 5.2.3 Demand

Demand consists of final and intermediate demand. Figure 5.1 describes the four-level nesting structure decomposing demand. Intermediate demand derives from the cost minimization problem described in section 5.2. In contrast, the regional household demand derives from the minimization of expenditure subject to a generalized Cobb-Douglas per-capita utility function augmented to include disutility of pollution. The Armington composite  $X_{(arm)i,r}$  represents aggregate domestic demand for good “i” described by 5-17.<sup>6</sup>

$$X_{(arm)i,r} = Q_{i,j,r} + X_{i,r} = [\alpha_{(D)i,r} X_{(D)i,r}^{\rho_{arm}} + \alpha_{(M)i,s} X_{(M)i,s}^{\rho_{arm}}]^{1/\rho_{arm}} \quad (5-15)$$

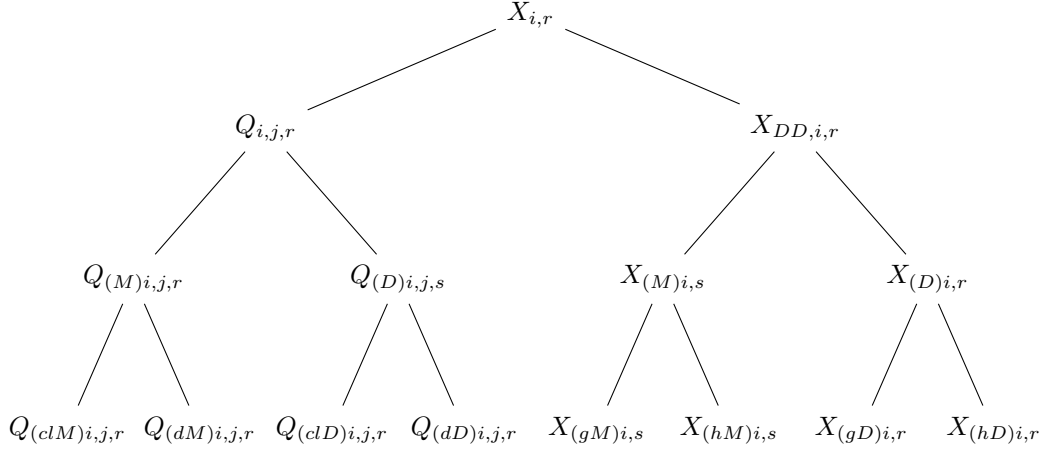
Where  $Q_{i,r}$  and  $X_{i,r}$  are intermediate and final Armington composite demands.  $\alpha_{(D)i,r}$  and  $\alpha_{(M)i,r}$  are share parameters.  $X_{(D)i,r}$  and  $X_{(M)i,r}$  represent total domestically sourced and imported good “i” respectively.  $\rho_{arm}$  is the Armington substitution parameter. Armington elasticities of substitution equal regional substitution elasticities  $\sigma_{arm} = \sigma_{reg}$ . This restriction allows for a uni-level Armington structure. More importantly, it allows domestic demand and foreign supply to compete in one market. Without this, the supply structure would involve different perceived elasticities for domestic and foreign demand.

In describing the demand nest, Figure 5.1 indicates that the top level nest decomposes total domestic demand into intermediate and final demand. The second level nest shows the CES decomposition of the intermediate composite into domestic and foreign sourced. Likewise, the right-hand sub nest describes the substitution possibilities between private and government consumption governed by Cobb-Douglas preferences. The left-hand side of the third level sub nest shows substitution possibilities between clean and dirty intermediates from both sources. It is worth mentioning that there is a fourth level nest, which decomposes

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<sup>6</sup>The Armington composite is a weighted combination of demand supplied by domestic and foreign producers.

Figure 5.1: Demand Decomposition



the dirty intermediates to specification intermediate goods. The numerical model includes this specification.

### Final Demand

A separable per-capita Cob-Douglas Utility function  $U_r$  describes the regional household's final demand. The regional household seeks to minimize expenditure (5-18) on private and government consumption, savings and pollution damage mitigation. Therefore, pollution generated by industrial consumption enters the regional utility function (5-19).

$$P_r X_r = E_h(P_h, U_h) + E_g(P_g, U_g) + P_s S + P_{pol} D_{pol} \quad (5-16)$$

$$U_r = U_h^{\beta_h} U_g^{\beta_g} S^{\beta_s} Z^{-\phi} \quad (5-17)$$

Where the regional price  $P_r$  index is an expenditure share weighted index of the average price of private and government consumption, price of savings and the shadow price of pollution, and  $X_r$ , total output produced in region r.  $P_h$  and  $P_g$  are price vectors,  $P_s$  the price of savings and  $P_{pol}$  the shadow price of pollution.  $\beta$ 's are the Cobb Douglas share parameters and  $\phi$  the disutility parameter. Finally,  $U_p$ ,  $U_g$ ,  $S$  and  $Z$  represent private household utility, government utility, savings and pollution damages.

Three restrictions apply to the above specification. First, savings and damages are treated as commodities. Second, government sub-utility is Cobb Douglas. Finally, private household preferences are non-homothetic. The latter is imposed to allow for changing budget shares as income and prices change. The general depiction of the regional expenditure function and three of the above restrictions derive from McDougall (2003). Based on the assumption of cardinality of the regional utility function, Hertel (2001) and McDougall (2003) introduce the concept of expenditure elasticity of utility as a factor explaining shifts in the regional utility function. They make a further assumption of unitary government and savings expenditure elasticities.

### Government Demand

Government generates income from income, factor and commodity taxes. It spends this income on domestic and imported commodities, and transfers a lump-sum to the regional household. Government preferences are Cobb-Douglas:

$$U_{g,r} = X_{(D)i,r}^{\beta_g} X_{(M)i,s}^{1-\beta_g} \quad (5-18)$$

$$Y_{(g),r} - T_r = P_{(gD)i,r} X_{(gD)} + P_{(gM)i,s} X_{(gM)i,s} \quad (5-19)$$

The usual restrictions of constant budget shares, unitary income elasticities, unitary own price elasticities and zero cross-price elasticities apply.

#### 5.2.4 Private Household Demand

Private household preferences are given by the CDES minimum expenditure:

$$E(P, U) = \sum_{i=1}^{10} B_i U_{(h)i,r}^{\rho_{cde}} \left[ \frac{P_{(h)i,r}}{P_{(h)} X_{(h)r}} \right]^{\rho_{cde}} \equiv 1 \quad (5-20)$$

where  $B$  and  $\vartheta$  are non-negative, and  $\rho_{cde}$  is either less than 1 for all none-negative values or less than zero for all  $i, s$ .  $U_{(h)r}$  and the term in the brackets are the private household utility and the normalized price for good “i” respectively, the numerator  $P_{(h)i,r}$ , is the highest price the consumer is willing to pay for good “i”, given price of other goods, expenditure (the denominator) and utility.  $B$ ,  $\vartheta$  and  $\rho_{cde}$  are the scale, expansion and substitution parameters.

The expansion parameter explains the non-homotheticity of the CDES function (Huff, Hanslow, Hertel and Tsigas, 1997). Further, the expansion and substitution parameters are related to the compensated and income elasticities. Solving for  $U_{(h)r}$  yields the indirect utility function as a function of normalized prices, which using Roy’s Identity and the Envelope Theorem yields the demand for the domestic commodity “i” (5-23). Further, pre-multiplication by the normalized price gives the expenditure share described by equation 5-24. Both equations are adopted from de Boer, Brocker, Jensen and van Daal (2006).

$$X_{(h)i,r} = \frac{B_i \left( \frac{P_{(h)i,r}}{Y_{(h)r}} \right)^{\rho_{(h)i}-1}}{\sum_{i=1}^{10} B_j \left( \frac{P_{(h)j,r}}{Y_{(h)r}} \right)^{\rho_{(h)j}}}} \quad (5-21)$$

$$\Theta_{(h)i,r} = \frac{B_i \left( \frac{P_{(h)i,r}}{Y_{(h)r}} \right)^{\rho_{(h)i}}}{\sum_{i=1}^{10} B_j \left( \frac{P_{(h)j,r}}{Y_{(h)r}} \right)^{\rho_{(h)j}}}} \quad (5-22)$$

Where  $Y_{(h)r} = P_{(h)r} X_{(h)r}$  and budget shares  $0 < \Theta_{(h)i,r} < 1$ ,  $\sum_{i=1}^{10} \Theta_{(h)i,r} = 1$

To capture how expenditure shares and income respond to market structure changes, equation 5-24 is totally differentiated with respect to expenditure  $Y_{(h)r}$  and the maximum price,  $P_{(h)i,r}$ . Further manipulation results in the following own price and income elasticities:

$$\eta_{(Y)r} = \sum_{j=1}^{10} (\rho_{(h)i,r} - \rho_{(h)j,r}) \Theta_{(h)i,r} \quad (5-23)$$

$$\mu_{(h)i,r} = \Theta_{(h)i,r} (\sigma_{(h)i} - \eta_{(Y)r}) \quad (5-24)$$

Where  $\sigma_{(h)i,r} = \sigma_{arm}$

The income elasticity of demand is a function of the CDE substitution parameters and the budget share. Equation 5-26 defines the own price elasticity as a function of income elasticity, the budget share, and elasticity of substitution given by the Armington substitution elasticity. It follows that equation 5-26 links private household activity to changes in market structure through the industry elasticity described by equation 5-16.

## Savings

Savings are a homogeneous commodity. Regional savings are gathered by a fictitious global bank to create an investment portfolio. Consequently, the savings rate is closely tied to the price of capital goods; it is region specific and adjusts with movements in the rental rate of capital.

## Disutility of Pollution

The pollution damage function  $Z(\omega, E, \lambda)$ , describes the relationship between emissions and pollution. Emissions result in pollution due to various factors such as the weather, ambient concentration and distance. The term  $\omega$ , the pollution conversion factor, captures all the processes that convert emissions into pollution. Equations 5-27 and 5-28 describe the pollution and damage function:

$$E_{pol,r} = \omega_r \sum_{v=1}^6 E_{v,r} \quad (5-25)$$

$$Z_r = \lambda_r(\omega, E_r) = \lambda_r E_{pol,r} \quad (5-26)$$

$\lambda_r(U, Y)$  and  $\omega_r E_r$  are the marginal utility of income, and regional pollution. Damages are therefore, the product of regional emissions and marginal utility of income.

### **5.2.5 Macro Closure**

To capture the effects of the policy shock on the trade balance, I assume endogenous government savings and exogenous taxes. Likewise, the trade balance is endogenous and the real exchange rate is treated as exogenous. Because regulation changes the distribution of relative costs across regions, these changes are bound to affect competitiveness through their effects on trade. To accommodate these changes, the real exchange is chosen as the numeraire. Finally, I assume savings driven investment. Therefore, investment levels adjust to the expected rate of return on regional investment.

### **5.2.6 Equilibrium Conditions**

General equilibrium is a set of prices such that the following three conditions are satisfied. First; firms earn zero economic profits. Second, commodity and factor markets are in equilibrium. Finally, the incomes balance. The equations describing these conditions are given in chapter 4. The first condition is worth elaborating because the number of firms is determined by the zero profit condition.

## **5.3 Application, Chapter Specific Data and Calibration**

The model is applied to Canada-EU trade. This application is timely because of the recent signing of a Canada-EU Comprehensive Economic and Trade Agreement (CETA). The two regions have distinct regulatory regimes. Canada's regime is predominantly standards based (Field and Olewiler, 2011), while the EU's regime is to a large extent market based; mostly environmental taxes and transferable discharge permits (Dresner, Dunne, Clinch and Beuermann, 2006). It may be efficient and beneficial for Canada to move to a market-based regime. For instance, In the case of carbon, the World Bank (2005) finds that standards reduce the trade balance by 10 percent, compared to the negligible effects of the carbon tax.

The database from chapter three is augmented to include measures of industrial concentration. I have borrowed data on the Herfindahl-Hirschman Index (HHI) from Elbehri and Hertel (2004) and have adapted it to this model. The HHI is a proxy for the concentration ratio. The inverse of the concentration ratio gives the number of firms that in this thesis is endogenously determined via the zero profit conditions. Scale data are derived from the same study. The model is calibrated to the GTAP vol. 6 database. A detailed description of the data is presented in chapter 3.

## 5.4 Simulation Design

Simulations are in two broad categories. The first set simulates effects of air emission levy harmonization and coordination when the real wages for the unskilled labor category is fixed. The second considers policy harmonization and coordination when wages for both labor categories are endogenous. Each set of simulations evaluates policy effects under FTA and no FTA scenarios. The purpose of this distinction is to ascertain whether free trade improves regulatory responses. Results in this chapter are later compared to those in chapters 4 and 6 to examine how market structure and the relative size of trading partners influence policy outcomes.

## 5.5 Simulation Results and Discussion

The analysis of real wage unemployment is relevant to the European experience. Therefore, analysis that ignores this reality can yield misleading costs and benefits of joint regulatory action. The literature dictates that regulatory policy in the presence of real wage rigidities has the potential to increase employment as optimizing firms substitute polluting intermediates for capital and labor. The results in the following section demonstrate that this may not always be the case; regulatory outcomes under imperfect competition tend to be unpredictable.

### **5.5.1 Effects of Collective Environmental Taxes in the Presence of Real Wage Rigidities**

In this section, I present results from policy shocks when the real wage for the unskilled labour category is fixed. The analysis of real wage unemployment is particularly relevant to the European experience. Analysis of the effects of collective regulatory action that ignores unemployment issues would be deficient. According to the literature, regulatory policy in the presence of real wage rigidities has the potential to increase employment as optimizing firms substitute polluting intermediates for capital and labor. The results in the following section demonstrate that this may not always be the case. Regulatory outcomes under imperfect competition can be unpredictable because policy shocks affect the structure of commodity markets.

#### **Output Effects under Fixed Wage Closure**

Output effects in the presence of real wage unemployment are tabulated in Figure 5.1. Figure 5.1 compares regulatory responses to coordinated and harmonized taxes under the no free trade and free trade assumptions. The term ASY\_IC refers to asymmetric regions competing in imperfectly competitive markets.

Table 5.1 shows that the EU experiences output falls relative to the baseline when environmental taxes are coordinated with a corresponding removal of border taxes. Surprisingly, results show that the region has 2.6 percent lower output when emission levies are zero. Here, the result is in part due to a fall in the equilibrium supply of capital as firms substitute capital for relatively cheaper intermediate goods. Capital is particularly important because it accounts for 10 percent of aggregate output. At the sectoral level, petroleum and coal production falls by 22.6 and 2 percent respectively. Similarly, output contracts by 1.9 percent when the emission levies are increased by \$10. In addition to the direct effects of increased costs on output, output falls because increased concentration in coal and manufacturing markets increases output inefficiencies associated with market power.

The introduction of free trade however results in output gains under all tax scenarios. Here efficiency gains associated with the removal of border taxes outweigh negative cost effects of the stringent policy stance.

Table 5.1: Output Effects under the Fixed Wage Closure: ASY-IC (% Change)

|        |              | Coordinated     |        |     | Harmonized   |        |      |
|--------|--------------|-----------------|--------|-----|--------------|--------|------|
|        | Initial      | New             | NO FTA | FTA | New          | NO FTA | FTA  |
| Canada | $\tau_{opt}$ | $\tau_E = 0$    | -0.3   | 3.9 | $\tau_{LB}$  | 0.2    | 0.6  |
| EU     | $\tau_{opt}$ | $\tau_E = 0$    | -2.0   | 2.8 | $\tau_{LB}$  | 2.8    | 0.0  |
| ROW    | $\tau_{opt}$ | 0.0             | -1.3   | 0.9 | 0.0          | -1.0   | 0.5  |
| Canada | $\tau_{opt}$ | $\tau_{opt}$    | -0.1   | 0.0 | $\tau_{WTD}$ | -2.2   | -4.0 |
| EU     | $\tau_{opt}$ | $\tau_{opt}$    | -0.2   | 1.0 | $\tau_{WTD}$ | -3.0   | -0.8 |
| ROW    | $\tau_{opt}$ | 0.0             | 0.0    | 2.0 | 0.0          | 0.3    | 0.0  |
| Canada | $\tau_{opt}$ | $\tau_E + \$10$ | 3.0    | 5.0 | $\tau_{UB}$  | -5.6   | 0.1  |
| EU     | $\tau_{opt}$ | $\tau_E + \$10$ | -1.9   | 1.1 | $\tau_{UB}$  | -1.0   | -0.4 |
| ROW    | $\tau_{opt}$ | 0.0             | 0.1    | 0.5 | 0.0          | 0.8    | 1.1  |

In contrast, Canada gains under all policy scenarios save the case when the optimal tax is applied in the absence of free trade. Gains are particularly larger in the presence of free trade. Under zero tax cum free trade scenario, output is 4 percent higher than the baseline compared to 0.5 percent when trade taxes are positive. Similarly, the 3 percent gain in output when the above optimal tax is applied independent of free trade is lower than the 5 percent when trade taxes are zero. When taxes are below optimal, direct output gains are due to increased capital which raises the investment component of GDP. Similarly, when the above optimal tax is applied, results show that the gains are largely due to an expansion in capital production. Both outcomes suggests that capital and polluting intermediates are substitutes. At the sectoral level, production in all other sectors falls in response to the above optimal. Contrary to theoretical predictions, labor markets are not sensitive to changes in regulatory choices in the presence of real wage rigidities. Nevertheless, the output gains confirm Cheikbossian (2010) who notes that the smaller region gains from

coordinating taxes with a larger one.

Table 5.1 also presents output effects of harmonized taxes in the presence of real wage rigidities. The table shows that both regions gain from minimum harmonized levies. In the absence of free trade, the EU's output is 2.8 percent higher than baseline. The region gains despite the relative cost disadvantage of harmonizing with Canada because the relatively higher production costs vis a vis Canada's cause firms to exit the sectors. The consequent rise in market concentration and scale efficiencies result in higher output relative to the baseline. It is worth mentioning that while the direct effects of the minimum schemes result in lower output, induced effects through changes in market structure more than offset the direct output losses. Further, the rise in capital induced by market changes more than offsets the reduction in capital due to the complementarity between capital and the regulated inputs in the intermediate to medium run. Nevertheless, free trade dampens these gains. According to Graham (1923), when markets are imperfectly competitive, free trade can result in losses because it can induce a reallocation of resources from scale efficient sectors.

Under the weighted and upper bound tax schemes the direct effect of relatively higher production costs causes the EU's output to fall. In addition, the equilibrium level of capital falls because capital and the polluting inputs are complementary. According to the results, the direct output and capital affects more than offset efficiency gains from scale economies. The net effect is a 3 and 1 percent fall in output relative to the baseline under the two tax scenarios. The fall in capital is particularly significant in the EU's capital-intensive sectors of gas and petroleum. Free trade significantly reduces these losses from weighted optimal and upper bound environmental taxes. The reduced production costs from the removal of border taxes increase the demand for both intermediate inputs and capital. Nevertheless, gains from free trade fail to offset the relative cost disadvantage of the harmonized tax scheme.

Compared to the coordinated scenario, Canada experiences higher regulatory costs in terms of foregone output when above minimum harmonized taxes are applied in the presence of real wage rigidities. These losses occur despite the relative cost advantages of

harmonizing with a lower tax region. While this may seem counter-intuitive, it is a likely outcome because the net output effects derive from four sources: the direct output changes associated with changes in production costs changes in demand, substitutability between inputs and induced effects through changes in market structure. Under the harmonized scheme, the first two effects raise output. However, if capital and labour are complements are capital is more substitutable with the polluting intermediate inputs, the return to capital falls and consequently the demand for capital and investment. Further, lower cost relative to the EU and the ROW induces entry. Entry of new firms causes a reallocation of resources from scale efficient sector. The resulting fall in scale economies reduces sectoral output. According to Table 5.1, the fall in output in the absence of free trade is 2.2 percent, compared to 4 percent when border taxes are removed. The removal of border taxes combined with relatively lower production costs increases sectoral competition but makes the incumbent firms less competitive. Here again, the scale efficiency effect dominates, and demand for capital and output fall.

In essence, under imperfect competition, the EU does better by combining regulatory policy with free trade. Unlike the analysis in the previous chapter, the EU's regulatory costs in the absence of trade are higher under both coordinated and harmonized scenarios. In the case of Canada, the region does better by coordinating taxes regardless the assumptions of free trade. In fact, free trade has mixed effects on Canada's regulatory outcomes. The region experience sizable losses from above minimum harmonized taxes, a result that seems to contradict Cheikbossian (2010). In the case of harmonized taxes however, free trade improves regulatory outcomes.

### **Trade and Competitiveness Effects under Fixed Wage Closure**

In this section, I consider the trade effects of environmental taxes in the presence of real wage rigidities. Trade effects are reflected in changes in the volume of trade, Terms of Trade (TOT), and comparative and competitive advantages. The assumption of intra-industry trade, a la Armington, implies that it is not possible to isolate changes in the pattern of

trade. For this reason, the analysis in this section centers on the composition of trade. Likewise, comparative advantage derives from scale efficiencies. I define competitiveness at firm level by examining changes in firm level profits via variations in market shares and firm level markups.

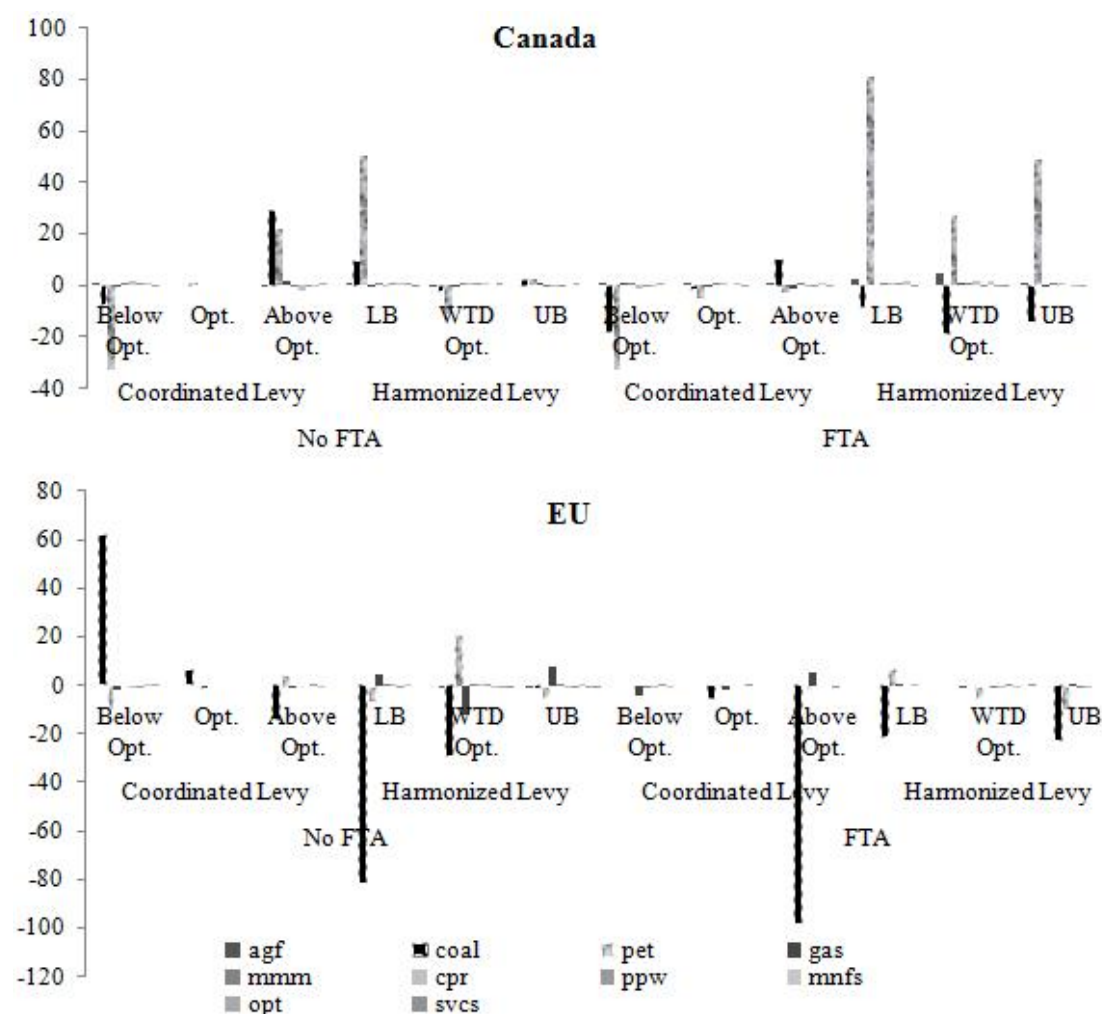
The empirical literature on the trade effects of regulatory policy is inconclusive. One strand maintains that aggregate trade flows are not sensitive to regulatory action. This groups comprises of earlier studies by Harris et al.(2002) and Tobey (1990), van Beers and van den Berg (1997). Another strand by Ederington and Minier (2003) and Markusen et al.(1993) finds that regulatory stringency affect trade flows. More recent studies by Babool and Reed (2005), Ederington (2010) and Jug and Mirza (2005) support this strand. While most of these studies rely on partial equilibrium gravity trade models, they all agree that regulatory policy has significant sector specific effects. The findings in thesis suggest that trade flows are not sensitive to joint regulatory policy but are sensitive to border tax changes. In support of earlier studies, the results suggest that sectoral flows are sensitive to changes in regulatory taxes.

Optimal environmental taxes in the absence of free trade result in changes in comparative and competitive advantages mainly in the coal, gas, petroleum, transport and manufacturing sectors. Figure 5.2 illustrates that the markups in the petroleum, coal and gas sectors are more sensitive to regulatory changes than the other sectors. The results suggest that in the absence of free trade, optimal environmental taxes have insignificant markets structure effects in both Canada and the EU. In contrast, the more stringent regulatory stance increases scale efficiencies in the three energy goods sectors and transport sectors.

Canada's petroleum, coal gas and transport sectors experience a rise in comparative advantage and becoming more concentrated. The latter results lend support to van Long and Soubeyran's (2005) concentration motive. Theory dictates that regulatory taxes applied without corresponding lump sum transfers are likely to reduce competitiveness. Therefore, regulatory taxes in the absence of free trade can potentially reduce competitiveness of the

industries using the regulated goods intensively. The simulation results for the three energy sectors suggest otherwise. According to Figure 5.2, markups in petroleum, coal and gas rise by 29, 22 and 1 percent respectively. Under imperfect competition with endogenous market structure, the result is plausible because higher production costs increase market concentration and the ability of firms to raise their markups. Free trade combined with the upper bound tax reverses scale efficiency gains in coal and petroleum, but results in scale expansion in the manufacturing sector. Corresponding markups fall by 1 and 3 percent in the gas and petroleum sectors and rise by 1 percent in manufacturing. Overall, Canada experiences minor changes in market share. Markups increase because the regulatory taxes affect marginal costs and the elasticity of demand.

Figure 5.2: Markup Changes under Fixed Wage Closure - ASY\_IC (%)



According to Figure 5.2, the EU's coal, petroleum and gas sectors is the most sensitive to regulatory tax changes. When taxes are coordinated in the absence of free trade, results reveal that the region's comparative advantage falls in all sectors save petroleum, and pulp and paper. Comparative advantage falls because the lower production costs from the removal of regulatory taxes results in entry and the crowding out of scale advantages. Importantly, the crowding out of scale economies is most significant in key scale intensive sectors like manufacturing. Similarly, the entry of firms reduces firm level markups in petroleum and coal by 15 and 12 percent. These results suggest that in the absence of free trade, not regulating intermediate inputs can result in the reallocation of resources from scale efficient sectors and a subsequent fall in aggregate output. Under free trade the region's comparative advantage in gas, petroleum, chemicals and metals falls. Correspondingly, markups fall by 1 and 4 percent in the petroleum and gas sectors respectively. Nevertheless, gains transport and service sectors more than outweigh the losses in all other sectors.<sup>7</sup> As in the case of Canada, optimal taxes have negligible market structure effects.

If instead, environmental taxes are above optimal, the EU's comparative advantage in petroleum rises. In contrast, comparative advantage in gas, manufacturing and services falls. Nevertheless, only the petroleum sector experiences a notable rise in competitiveness as firm level markups rise by 4 percent. Under free trade, only the gas and manufacturing sectors experience significant changes in market structure. The two sectors experience a rise in scale advantages and become more concentrated; trade flows in manufacturing rise. Moreover, because the two sectors are capital intensive, the rise in the demand for capital results in net output gains.

Changes in market structure are stronger when environmental taxes are harmonized. As in the previous paragraphs, coal, petroleum and gas sectors are relatively more sensitive to regulatory changes than the other three regulated sectors. The upper and lower panels of Figure 5.2 illustrate shifts in competitiveness between the two regions. According to Figure 5.2, Canada's petroleum sector is the most responsive to regulatory changes. In contrast, the EU's coal sector is the most policy responsive among the three energy producing sectors.

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<sup>7</sup>Only the petroleum sector experiences a 1.2 percent loss in market share

Beginning with the effects of harmonized taxes on Canada in the absence of free trade, Figure 5.2 shows that when taxes are lower bound, firm level markups rise by 50 percent in the petroleum sector. Likewise, markups in the manufacturing sector rise by 1 percent. The results also suggest that when taxes are minimum, Canada's sectors generally experience the crowding in of scale efficiencies and as a consequence a gain in comparative advantage. When the taxes are weighted optimal, Canada's experiences a fall in comparative advantage in manufacturing, transport, services and metals sectors. Correspondingly, markups in manufacturing fall by 8 percent. Markups for firms in the agriculture, coal, petroleum, gas and chemical sectors a rise by 1, 5, 17, 1 and 1 percent respectively. If instead, the harmonized scheme is upper bound, the region's comparative advantage in key sectors falls.

Under free trade, Canada gains scale efficiencies in petroleum, metals, chemical, paper and chemical sectors when taxes are lower bound. Similarly, firms in these sectors become more competitive as markups rise by 10, 3, 2 and 1 percent. The latter results show that a less than optimal policy stance can improve competitiveness in petroleum and non-energy regulated sectors. The lower bound tax scheme has the opposite effects on other sectors like gas and coal. Nevertheless, under free trade, competitiveness and comparative advantage losses occur only in the coal and pulp and paper sectors. All other sectors become more concentrated, despite the lower production costs associated with the lower bound tax scheme because relative to the EU, Canada's internal market is significantly smaller, therefore the removal of border taxes does not result in significant changes in prices relative to the EU. Gains in competitiveness occur under both weighted and upper bound harmonized schemes. Notwithstanding, only the petroleum sector experiences a significant rise in firm level markups under the upper bound scheme. While petroleum and manufacturing sectors gain comparative advantage under the weighted optimal scheme, only petroleum gains when the regulatory taxes are upper bound. Over all, the results suggest that the petroleum sector gains comparative cost advantages and becomes more competitive when regulatory taxes are harmonized.

Harmonized taxes generally crowd out scale economies in the EU. This is because the harmonized scheme raises unit costs and the rise in unit costs has a stronger effect that

the increased benefits of supplying a larger market. Further, results suggest that markup changes occur mainly in the three energy sectors. The fall in petroleum markups and economies in the absence of free trade make the firms in the industry less competitive. This result extends to weighted and upper bound taxes under free trade, the changes are however negligible. For coal, policies combining harmonized taxes and free trade results in falling markups and increased competition. However, the pro-competitive effects are not strong enough to increase output at the aggregate level because coal accounts for less than 0.7 percent of aggregate output.

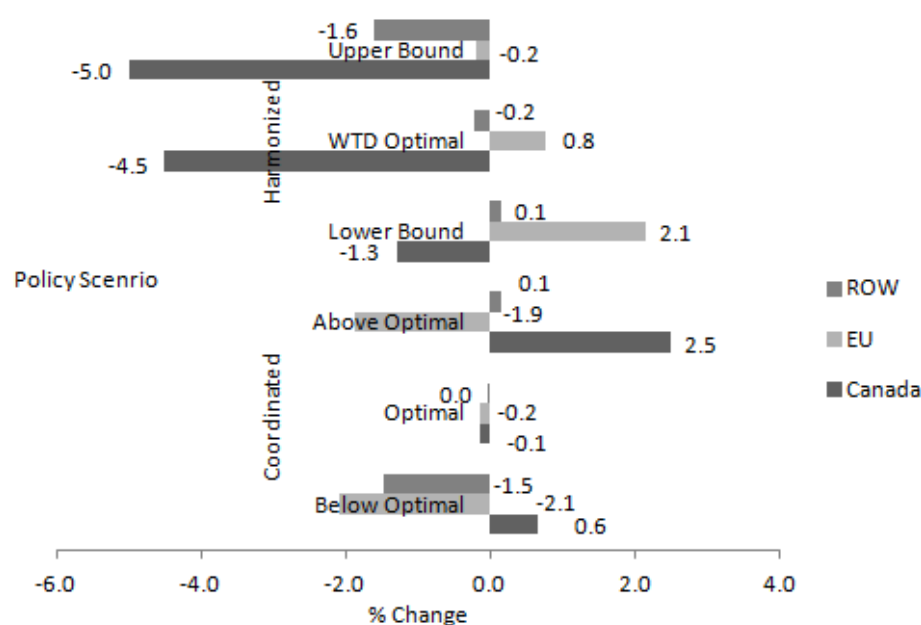
### **Welfare Effects under Fixed Wage Closure**

Welfare changes under the assumption of imperfect competition and IRTS are complex. The complexities arise because changes in welfare are the net effect of changes in output, trade and pollution, and market power. Variations in market structure, for instance, can result in welfare losses market power increases. Increased market power implies firms are able to restrict output and raise prices, and consequently reduce utility. Moreover, inefficiency due to under utilization of resources reinforces welfare losses. Depending on the shock, market induced effects can dampen gains in welfare that result from lower pollution or reinforce welfare losses due to under regulation. Theoretically, free trade has pro-competitive effects because the removal of tariffs reduces barriers to entry. By increasing the number of firms, free trade reduces scale efficiencies and firm level mark-ups and consequently, market power. Efficiency losses from the reduction in scale economies dampen efficiency gains from higher output and the reduction of resource underutilization. The net welfare effect from induced changes in market structure depends on which of the two effects is stronger.

As in chapter 4, the Equivalent Variation (EV) measures changes in welfare. For meaningful comparisons, I use percentage welfare changes measured by the ratio of EV to initial (baseline) income. Figures 5.3 illustrate welfare effects of environmental taxes in the presence of real wage rigidities under the no free trade scenario. Likewise, welfare from combining regulatory taxes with free trade are illustrated by Figure 5.4 below. The results

reveal that when regulatory taxes are applied in the absence of free trade, welfare losses are higher under the harmonized scheme. For instance, Figure 5.3 shows that welfare changes range from  $-2.9$  percent to  $2.5$  percent when regulatory taxes are coordinated compared to  $-5.8$  percent to  $3.4$  percent under the harmonized scheme. However, the EU experiences welfare losses from all taxes scenarios when taxes are coordinated, and the weighted optimal scheme when taxes are harmonized. In contrast, Canada's welfare falls when coordinated taxes are either optimal or below optimal. Similarly, welfare is lower when harmonized environmental taxes are minimum and upper bound.

Figure 5.3: Welfare Effects under Fixed wage no FTA Closure - ASY-IC

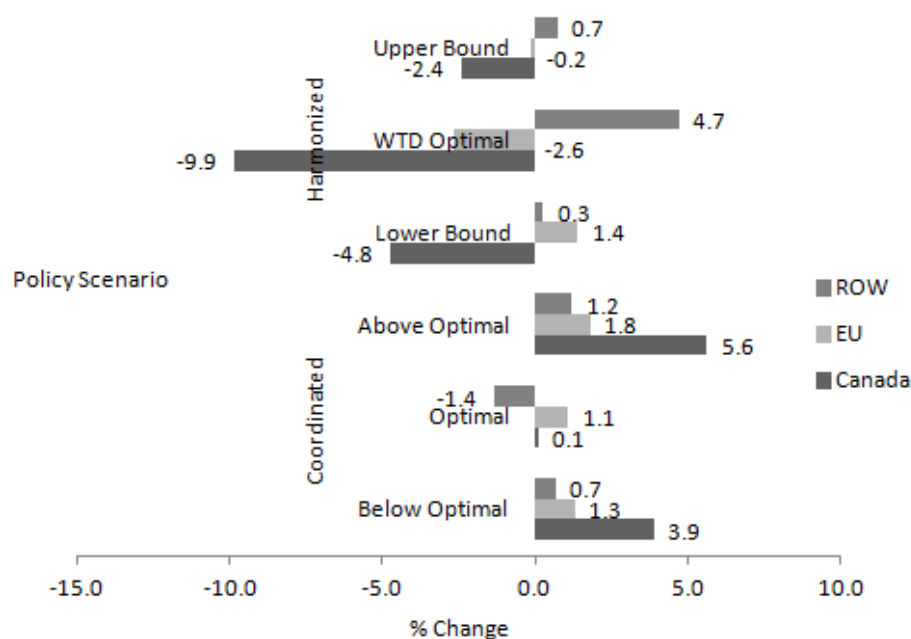


Under the coordinated scheme, welfare costs are highest under the above optimal tax scheme. The 1.9 percent fall in welfare corresponds to the 1.9 percent fall in aggregate output reported in Table 5.1. The fall in pollution of 3.2 percent has negligible welfare effects. When trade is liberalized, Figure 5.4 indicates that gains from free trade more than offset welfare losses from coordinated taxes. When environmental taxes are positive, the EU's welfare rises by 1.1 and 1.8 percent when taxes are weighted optimal and above optimal. These gains correspond to the 1.1 percent rise in output reported in Table 5.1.

If instead, regulatory taxes are harmonized, Figure 5.3 shows that in the absence of free

trade EU's welfare is higher than baseline under the lower bound and weighted optimal tax scenarios. Welfare under the two schemes is 2.1 and 0.8 percent higher than baseline. The logic in this case is simple. When the EU harmonizes with Canada, its production costs are relatively higher than Canada. In the first instance, the lower bound tax scheme, welfare rises because Canada's relative production costs are significantly lower invariably raising the EU relative costs. Higher welfare derives mainly from a 2.8 percent rise in output and minor 1.4 percent reduction in pollution. Welfare effects associated with the upper bound tax are insignificant because output only falls by 0.4 percent. Pollution, however, falls by 6.3 percent. The removal of border taxes has adverse effects welfare effects when the EU adopts a harmonized scheme in the presence of real wage rigidities. Expressly, free trade reduces gains from minimum harmonized taxes and reverses gains from the weighted optimal tax scheme. In either case, lower welfare derives mainly from output effects.

Figure 5.4: Welfare Effects under Fixed wage FTA Closure - ASY\_IC (% Change)



In the absence of free trade, Canada experiences higher welfare when coordinated taxes are above optimal. Figure 5.3 reveals that welfare under the above optimal scheme rises by 2.5 percent, the results of a combined 5.4 percent fall in pollution and a 3 percent rise in aggregate output. Gains in welfare are larger under free trade. According to Figure

5.4, welfare under free trade is 5 percent higher than baseline. Similarly, when free trade is applied in the absence of regulation, welfare rises by 3.9 percent. When environmental taxes are zero, the gain in welfare associated with higher production is stronger than the loss in welfare from a 12.4 percent rise in pollution. For the above optimal tax, the improvement in welfare derives from a 5.4 percent fall in pollution and a 3 percent rise in output. These changes are reinforced by gains from trade and increased efficiency from the increased scale efficiencies in manufacturing and services.

While tax harmonization affords Canada cost advantages relative to its trading partner, these benefits do not translate into welfare gains. For instance, welfare falls by 1.3 and 4.5 percent when a environmental taxes are lower bound and weighted optimal respectively. Output dynamics reinforced by pollution increases explain the losses in welfare. The lower than baseline welfare under the weighted scheme derives from a combination of a 3.1 percent fall in output and a corresponding 6.8 percent rise in pollution reported in Table 5.3 of appendix 5.4. This result is inconsistent with Cheikbossian (2010) who finds a harmonized tax scheme to benefit the smaller region. Likewise, it departs from earlier findings by Hamilton and Duval (2004) that when asymmetries are based on the distribution of the consumer base, harmonization has superior welfare effects. My results differ from these studies because my analysis assumes the presence of real wage rigidities and is based on general equilibrium analysis. Welfare costs are exacerbated under free trade. Despite having pro-competitive effects, free trade worsens welfare because it reduces scale efficiencies and increases pollution.

### **5.5.2 Effects of Environmental Taxes When Wages are Flexible**

#### **Output Effects under Flexible Wage Closure**

The removal of the labor market constraint results in weaker output effects. The results reveal that the range of output changes is significantly narrower when wages are flexible compared to the fixed wage case. Table 5.2 displays output effects from coordinated and

harmonized environmental taxes in the presence of flexible wages. Comparing output effects of the two regulatory approaches, Table 5.2 shows that the output costs are higher under the harmonized scheme. Further, while free trade generally improves regulatory outcomes for the EU under both regulatory approaches, gains from free trade are higher when environmental taxes are harmonized. According to Table 5.2, under the coordinated tax scheme, output changes range from  $-1.2$  percent to  $0.6$  percent in the absence of free trade, and  $-3.3$  to  $2$  percent under free trade. Likewise, harmonized scheme results in output effects ranging from  $-1.4$  to  $1$  percent under the no free trade assumption, and  $-3.2$  to  $1.1$  percent when border taxes are zero.

Table 5.2: Output Changes under Flexible Wage No FTA Closure- ASY\_IC (%)

|        | Coordinated  |                 |        |      | Harmonized   |        |      |
|--------|--------------|-----------------|--------|------|--------------|--------|------|
|        | Initial      | New             | NO FTA | FTA  | New          | NO FTA | FTA  |
| Canada | $\tau_{opt}$ | $\tau_E = 0$    | 0.6    | 1.2  | $\tau_{LB}$  | 0.6    | 1.1  |
| EU     | $\tau_{opt}$ | $\tau_E = 0$    | 0.6    | 2.0  | $\tau_{LB}$  | 0.0    | -0.1 |
| ROW    | $\tau_{opt}$ | 0.0             | -0.3   | -0.8 | 0.0          | 0.0    | 0.0  |
| Canada | $\tau_{opt}$ | $\tau_{opt}$    | -0.3   | -3.3 | $\tau_{WTD}$ | -0.3   | -3.2 |
| EU     | $\tau_{opt}$ | $\tau_{opt}$    | -0.1   | 1.6  | $\tau_{WTD}$ | 1.0    | -2.6 |
| ROW    | $\tau_{opt}$ | 0.0             | 0.0    | -0.5 | 0.0          | -0.4   | 1.1  |
| Canada | $\tau_{opt}$ | $\tau_E + \$10$ | 0.6    | -0.5 | $\tau_{UB}$  | -1.3   | -0.1 |
| EU     | $\tau_{opt}$ | $\tau_E + \$10$ | -1.2   | -0.1 | $\tau_{UB}$  | -1.4   | 0.4  |
| ROW    | $\tau_{opt}$ | 0.0             | 0.5    | 0.1  | 0.0          | 0.6    | -0.1 |

Starting with coordinated taxes in the absence of free trade, Table 5.2 shows that output effects for Canada and the ROW are minor. Likewise, the EU's change in output associated with an optimal tax scheme is trivial. Nevertheless, the EU's output under the above optimal scheme falls by 1.2 percent. The fall in output is the net effect of higher production costs, substitution between capital and the regulated intermediate inputs, and the distortionary effect of increased market power. At first glance, the capital effect might seem counter intuitive; however, the outcome reflects the likelihood that capital bears a

significant proportion of the regulatory burden. According to Heutel and Fullerton (2007), if labour and capital are complementary and capital is the more substitutable primary input, a rise in the cost of intermediates would reduce the return to capital. Therefore, both capital and investment fall, consequently driving down aggregate outcome. At the sectoral level, higher production costs also induce higher cost firms to exit the markets. While the exit of firms can result in higher output due to increased scale efficiencies, it also increases market power. Free trade weakens the direct cost and market power effects, hence the improvement regulatory outcomes. The case of the EU explicitly illustrates the importance of efficiency effects of free trade.<sup>8</sup> Nevertheless, gains from free trade are not strong enough to offset the adverse output effect associated with above optimal tax.

In the case of Canada, results in Table 5.2 suggest that for positive tax levels, free trade actually worsens regulatory outcomes. In essence, when wages are flexible, coordinated taxes combined with free trade exert significant costs on the region. Further, when border taxes are zero, maintaining optimal taxes while the third region is unregulated results in a 3.3 percent output contraction. This result is largely due to a 12 percent fall in the rate of return to capital, which causes the equilibrium supply of capital to fall by 16.9 percent. At the sectoral level, coal production falls by 1.2 percent and agriculture by 0.7 percent. Output responses in all other sectors are negligible. In fact, results in Table 5.2 suggest the region does better by not regulating polluting intermediates when trade is liberalized.

The last two columns of Table 5.2 display effects of harmonized taxes under no free trade and free trade assumptions respectively. In the absence of free trade, the regulatory losses only occur under the upper bound harmonized tax scheme. When regulatory taxes are upper bound, output falls by 1.3 and 1.4 in Canada and the EU respectively. Canada's lower than baseline output derives mainly from changes in market structure. Recall that environmental tax harmonization confers a relative cost advantages on Canadian firms vis a vis EU firms. For this reason, direct output effects are positive. However, lower relative production costs attract the entry of new firms and the consequent crowding out of scale

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<sup>8</sup>The results also suggest that regulatory policy has minor effects on employment, a result consistent with Elliot and Cole (2007).

efficiencies. In contrast, the EU's output falls by 1.4 because the EU intermediates are over-regulated. The fall in output derives from the direct effects of higher production costs, the possibility of higher complementarity between capital and labour, and the fall in scale efficiencies in unregulated sectors like manufacturing. In contrast, the weighted optimal scheme raises the EU's output by 1 percent above the baseline level. The rise in output derives from the crowding in of scale economies and reduced output distortionary effect associated with a market power. The results suggest firm level markups fall by 52, 2.9 and 1 percent in the coal, gas and petroleum sectors.

Unlike the coordinated tax outcomes, free trade has mixed effects on both Canada and the EU when corrective taxes are harmonized. In case of the EU, only improves regulatory outcomes when harmonized taxes are upper bound. Table 5.2 suggest that the efficiency gains from free trade are reverse the 1.4 output loss in the absence of free trade, to a 0.4 percent gains. In contrast, free trade reverses output gains from a weighted optimal scheme as exemplified by the shift in output from 1.1 percent under the no free trade assumption to  $-2.6$  percent. While the weighted scheme is skewed towards the EU's lower baseline environmental taxes, it is not as restrictive as the lower and upper bound schemes. This difference in output between the two trade scenarios is due in part to the fall in scale economies in capital-intensive manufacturing, metals and petroleum sectors. In fact, the results reveal that the change in the structure of the manufacturing sector is a key factor explaining the different regulatory outcomes.

Canada experiences a significant 3.2 percent fall in output under the weighted optimal tax cum free trade policy. Nevertheless, unlike the EU, the loss is associated with induced effects of lower production costs. Specifically, the region's petroleum and gas sectors experience losses in competitiveness. The two sectors experience a 1.1 fall and 0.6 percent in market share and a 22.6 and 1.3 percent fall in equilibrium output. In addition, the contraction of these two industries and the fall in the regional rate of return reduce equilibrium capital by 14 percent.

## Trade and Competitiveness Effects under Fixed Wage Closure

Effects of regulatory changes on trade flows under the flexible wage assumption mirror outcomes under the fixed wage closure. First, aggregate trade flows are not responsive to regulatory choices unless the environmental taxes are combined with free trade. Second, sectoral trade flows are sensitive to regulatory choices. Notwithstanding, sectoral dynamics are different because the removal of the wage constraints allows for easier substitution between inputs. Figure 5.5 below, illustrates changes in firm level markups associated with the four policy scenarios.

Induced market structure effects under the flexible wage closure exhibit a slightly different pattern compared to the fixed wage case. For instance, Figure 5.5 reveals that almost all of Canada's sectors respond to the regulatory shocks, but changes in key sectors like petroleum are less pronounced. This is because, when wages are flexible, part of the regulatory pulse is absorbed through the adjustment in wages. Changes the EU's coal sector exhibit a similar pattern. Nevertheless, like market structure changes under the fixed wage closure, the most policy sensitive sectors are petroleum for Canada, and coal for the EU.

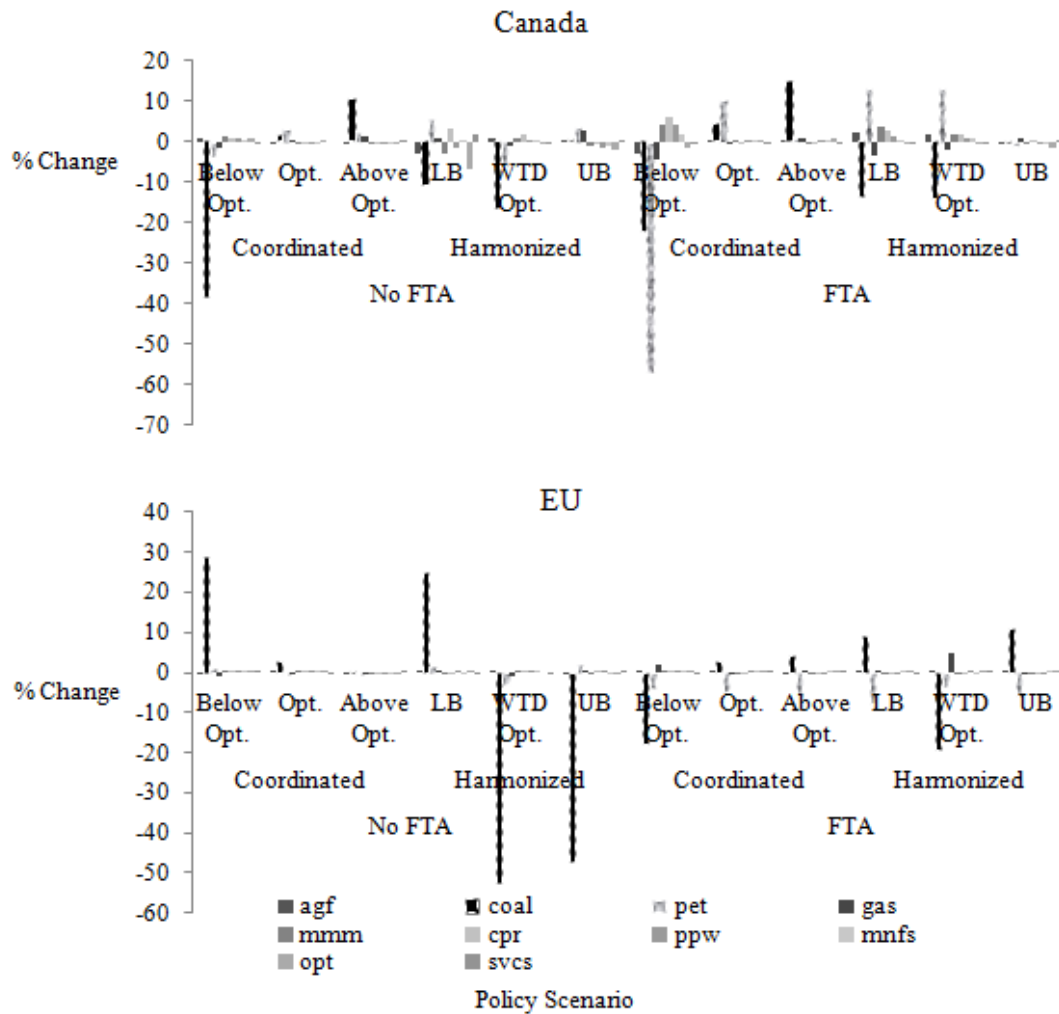
Beginning with the effects of coordinated taxes on Canada's sectors, the results reveal an interesting distinction between energy commodity and non-energy commodity sectors. In particular, regulated energy sectors (coal, petroleum and gas) sectors become more concentrated with regulatory stringency. The opposite is true for the non-energy regulated sectors (chemicals, metals and pulp and paper). Importantly, the manufacturing sector is sensitive to regulatory choices in the energy and non-energy sectors and is the main determinant of the net effect of market structure changes on overall economic activity. A shock setting environmental taxes to zero in the absence of free trade results in the reallocation of resources and a fall in competitiveness in the three energy sectors as firm level markups fall by 39, 3 and 2 percent in the coal, petroleum and gas sectors. The metal, chemical, and pulp and paper sectors experience a minor rise in firm level markups of 1 percent each. According to the results, maintaining optimal taxes in Canada and the EU, while an intermediate in the ROW has minor market structure effects.

On the other hand, when regulatory taxes are above optimal, the coal, petroleum and gas sectors gain both comparative and competitive advantages. Gains in competitiveness are reflected in the 11, 2 and 1 percent rise in firm level markups. Conversely, comparative and competitive losses occur in the non-energy sectors. The distinction in regulatory responses derives mainly from differences in perceived elasticities. The pattern of market structure changes under free trade result in positive output gains because of significant gains in scale economies in manufacturing. However, free trade magnifies losses in the petroleum sector when taxes are zero, as illustrated by the sharp fall in petroleum markups in Figure 5.5.

Comparisons between the upper and lower panels of Figure 5.5 reveal notable differences between structural changes in Canada and the EU. Unlike Canada, not all sectors are sensitive to regulatory choices in the EU. Structural changes are limited to the three energy sectors. Further, the coal sector in particular, experiences significant changes in competitiveness. Shifts in comparative costs in response to coordinated taxes are also muted. Figure 5.5 also shows that competitiveness changes are stronger under a coordinated cum free trade policy. Unlike Canada, the EU's petroleum sector experiences comparative and competitive advantages losses when coordinated taxes are positive. Essentially, coordinated taxes cause shifts in comparative advantage in petroleum production from the EU to Canada. Petroleum markups fall by 5 and 6 percent under optimal and above optimal tax schemes. When taxes are optimal the EU enjoys a 1.3 percent rise in aggregate output because the weighted taxes reduce the distortionary effect of market power. Further, the EU has the benefit of a larger internal market.

If instead, regulatory taxes are harmonized, the EU's petroleum sector loses competitiveness when harmonized environmental taxes are combined with free trade. In contrast, the coal sector's loses competitiveness when weighted optimal taxes are applied in the absence of free trade. For both coal and petroleum, competitiveness falls in response to harmonized tax cum free trade policy. In contrast, the capital-intensive gas sector enjoys higher markups.

Figure 5.5: Markup Changes under Flexible Wage Closure - ASY\_IC (%) )



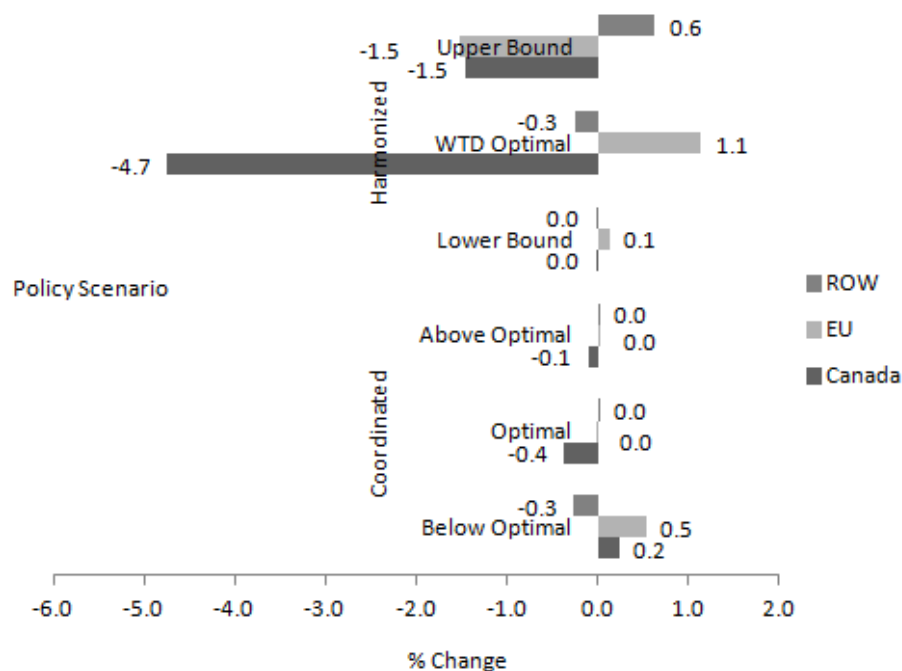
For Canada, all 10 sectors are sensitive to changes in harmonized taxes. Agriculture, coal, metals and pulp and paper lose competitiveness under the lower bound tax scheme. Interestingly, petroleum, gas and chemical sectors become more competitive as markups rise by 5, 1 and 3 percent. The two sectors experiences gains in firm level markups when the cost advantages from harmonizing with the EU are largest (lower bound and upper bound tax schemes). In particular, firm level markups are 5 and 1 percent higher than baseline when taxes are lower bound, and 3 and 3 percent higher than baseline under the upper bound scheme. The weighted optimal and lower bound scheme under free trade result in competitiveness gains for non-energy sectors. In essence, whether or not lower regulatory targets result in competitiveness gains depend on the sector and the perceived

elasticities. The preceding discussion results suggest that competitiveness losses are possible when regulatory taxes are zero or minimum.

## Welfare Effects under The Flexible Wage Closure

Figures 5.6 and 5.7 illustrate welfare effects under the no free trade and free trade assumptions when wages are fully flexible. Results in Figure 5.6 reveal that in the absence of free trade, welfare losses are negligible when environmental taxes are coordinated, but significant when taxes are harmonized. For instance, Canada's welfare costs under weighted optimal and upper bound harmonized taxes schemes are 4.7 and 1.5 percent. The 4.7 percent fall in welfare under the weighted optimal scheme derives mainly from a loss in efficiency in key sectors like manufacturing and services and a 6 percent rise in pollution. In contrast, welfare falls under the weighted optimal scheme because aggregate output falls by 1.3 percent and the contraction in employment in all non energy sectors.

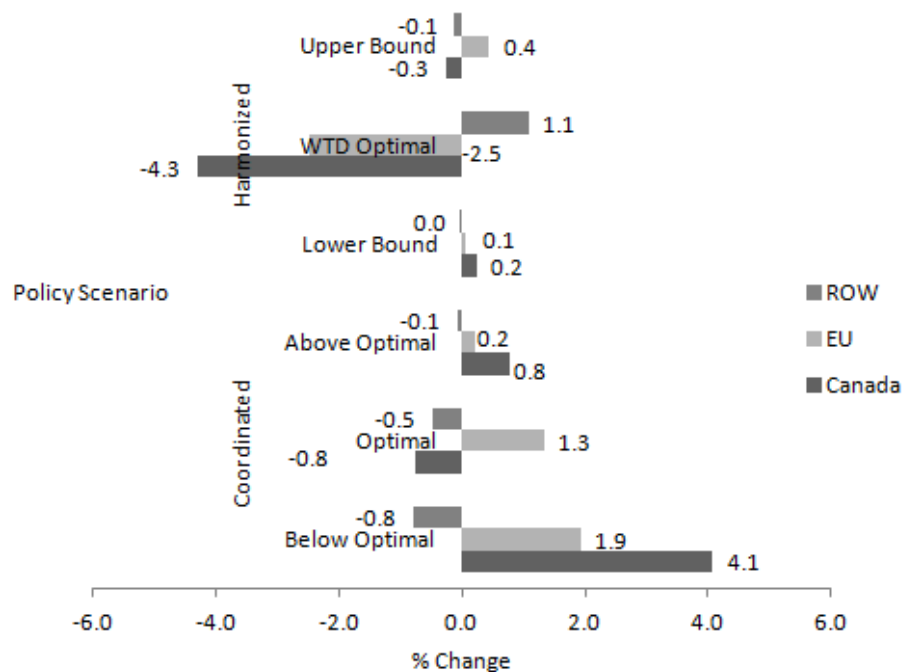
Figure 5.6: Welfare Effects under Flexible Wage No FTA Closure - ASY\_IC



Despite the cost disadvantage of harmonizing with a higher tax region, the EU's welfare is 1.1 percent higher than optimal under the weighted optimal scheme. According to

Table 5.5 in appendix 5.A, pollution falls by only 0.7 percent. It follows therefore that the favourable welfare effect derives mainly from a rise in aggregate output. This result is consistent with Keen et al.(2002) who posit that under imperfectly competitive markets, weighted harmonized taxes based on initial taxes have superior welfare effects. The EU's welfare under the upper bound environmental tax scheme falls by 1.5 percent due to a 1.4 percent fall in aggregate output and a contraction in skilled labour employment in all sectors. While Table 5.5 in appendix 5.A reveals that the upper bound tax scheme reduces pollution by 5.9 percent, the gain in welfare from lower pollution only partially offsets losses from output and employment.

Figure 5.7: Welfare Effects under Flexible Wage FTA Closure - ASY\_IC



The literature review in chapter 2 reveals that when TOT are sensitive to trade policy changes, free trade has the same effect as direct lump sum transfers (Turunen-Red and Woodland, 2004). Further, the discussion in the preceding subsection reveals that higher stringent regulatory taxes increase both market concentration and scale efficiencies. Following Katsoulacos and Xepapadeas (1995) who posit that a lump sum transfer that increases market concentration can be welfare improving, a combination of free trade and a stringent policy stance should be welfare improving. Figure 5.7 reveals that this prediction is gener-

ally true for the EU. Nevertheless, free trade reverses the region's welfare gains under the harmonized weighted optimal scheme. This is because presence of free trade results in the reallocation of resources in the manufacturing sector and a fall in skilled labour employment across all sectors.

The effects of combining joint regulatory policy with free trade on Canada's welfare are mixed. First, Figure 5.7 reveals that free trade benefits the region if it chooses not to tax polluting intermediates. In particular, welfare is 4.1 percent above the baseline when regulatory taxes are zero. Apart from the weighted optimal tax scheme, policies combining positive environmental taxes with free trade have negligible welfare effects. When taxes are weighted optimal, gains from free trade reduce the welfare loss, but are not strong enough to offset the 4.7 fall in welfare in the absence of free trade. This is in part due to the significant contraction in skilled labour employment and a 5 percent fall in pollution. The results suggest that weighted optimal taxes when wages are flexible result in welfare losses regardless of the assumption of the trade assumption. This outcome contradicts Cheikbossian (2010), Hamilton and Duval (2004), Keen et al. (2002). While Cheikbossian, and Hamilton and Duval discuss harmonization of environmental taxes, their analyses does not consider the impact of pollution changes on welfare. In addition, they ignore employment effects and their tax specification ignores labour market inefficiencies. In general, the results discussed in this subsection suggest that environmental tax cum free trade policies do not always result in welfare gains. In essence, purported gains from trade under increasing returns may not be enough to offset high costs of regulatory policy. Further, the possible reallocation of resources from large scale economies imply that free trade can potentially reduced welfare.

## 5.6 Conclusion

Results in this chapter indicate that policy outcomes are sensitive to the choice of regulatory approach and labor market considerations. Further, contrary to theoretical predictions, free trade does not always result in favorable policy outcomes, especially for the smaller region.

Overall, the results suggest that regulatory costs in terms of foregone output, are higher for the EU when real wages are rigid. This result is particularly true when coordinated taxes are applied in the absence of free trade. Gains from free trade, however, more than offset the EU's regulatory costs under the coordinated scheme. In contrast, Canada generally has better policy outcomes when coordinated taxes are applied in the presence real wage rigidities. In fact, coordinated taxes under the fixed wage closure yield the most gains for the region. Under the flexible wage closure, Canada can avoid regulatory losses by retaining positive border taxes or not regulating it intermediates when border taxes are removed. Results therefore suggest that in the short to medium run, the EU does better by combining coordinated taxes with free trade. The preceding discussion also reveals that output effects are smaller when environmental taxes are harmonized compared to coordinated. In essence, when markets are imperfectly competitive, harmonized taxes are the less costly. Importantly, free trade does not always improve Canada's regulatory outcomes. Likewise, when taxes are harmonized, in the presence of real wage rigidities, free trade results in net regulatory losses for the EU.

From the literature, it was established that competitiveness concerns are the main argument in support of harmonized taxes. The above analysis suggests that the energy based intermediates especially petroleum and coal, are the most sensitive to tax induced changes. For the EU, coal exhibits inferior good characteristics; a fall in price due to the removal of taxes, results in an expansion of the coal sector. In the absence of real wage unemployment, the region preserves its competitiveness position and market structure. Real wage unemployment however, results in increased concentration when above optimal coordinated taxes are combined are with positive trade taxes. On the contrary, all other tax scenarios have pro-competitive effects. Therefore if the objective is increased market concentration, this can be achieved by combining a stringent policy stance with trade taxes. Results suggest that almost all of Canada's sectors are sensitive of policy shocks. More importantly, coordinated taxes cum trade have pro-competitive effects. These are particularly stronger when the economy is at full employment. However, harmonized taxes in general increase market concentration.

Welfare effects are more complex because the net effect depends on four equally important effects. The key observation is that welfare changes are sensitive to labor market considerations. In the presence of real wage rigidities and imperfect competition, harmonization combined with free trade results in lower welfare for both Canada and the EU. In contrast, free trade reverses welfare losses under coordinated taxes. When the economy is at full employment, welfare changes for the EU under imperfect competition are lowest under harmonized taxes. For the above optimal coordinated environmental taxes, taxes applied without a corresponding removal of border taxes has adverse welfare effects on the region. Policy harmonization when the economy is at full employment imposes negligible welfare costs on the region.

The above interactions suggest that the choice of policy under imperfect competition depends on the objectives of the regulator whether its regulatory cost minimization or enhancing competition or welfare. The next chapter analyzes policy effects when two symmetric regions trade in imperfect markets.

## Appendix 5.A

Table 5.3: Pollution Changes under Fixed Wage No FTA Closure- ASY\_IC (%)

|        | Coordinated E-Taxes |              |                 | Harmonized E-Taxes |              |             |
|--------|---------------------|--------------|-----------------|--------------------|--------------|-------------|
|        | $\tau_E = 0$        | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$        | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 11.6                | 0            | -5.4            | 1.2                | 4.6          | -0.2        |
| EU     | 6.1                 | -0.1         | -3.2            | -1.2               | -1           | -6.3        |
| ROW    | 10.3                | 10           | 9.7             | 10.2               | 10.3         | 10.1        |

Table 5.4: Pollution Changes under Fixed Wage FTA Closure- ASY\_IC (%)

|        | Coordinated E-Taxes |              |                 | Harmonized E-Taxes |              |             |
|--------|---------------------|--------------|-----------------|--------------------|--------------|-------------|
|        | $\tau_E = 0$        | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$        | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 5.6                 | 0.5          | -3.8            | 5.0                | 5.1          | -0.1        |
| EU     | 4.6                 | -1.1         | -4.1            | -1.6               | -1.3         | -6.5        |
| ROW    | 10.2                | 10.2         | 10.7            | 10.1               | 10.2         | 10.2        |

Table 5.5: Pollution Changes under Flexible Wage No FTA Closure- ASY\_IC (%)

|        | Coordinated E-Taxes |              |                 | Harmonized E-Taxes |              |             |
|--------|---------------------|--------------|-----------------|--------------------|--------------|-------------|
|        | $\tau_E = 0$        | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$        | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 14.7                | -0.2         | -2              | 5.7                | 6.1          | -0.2        |
| EU     | 5.4                 | 0            | -5.5            | 0.3                | -0.7         | -4.9        |
| ROW    | 10.2                | 10.2         | 9.7             | 10.1               | 10.2         | 10.2        |

Table 5.6: Pollution Changes under Flexible Wage FTA Closure- ASY\_IC (%)

|        | Coordinated E-Taxes |              |                 | Harmonized E-Taxes |              |             |
|--------|---------------------|--------------|-----------------|--------------------|--------------|-------------|
|        | $\tau_E = 0$        | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$        | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 5.6                 | 0.5          | -3.8            | 5.0                | 5.1          | -0.1        |
| EU     | 4.6                 | -1.1         | -4.1            | -1.6               | -1.3         | -6.5        |
| ROW    | 10.2                | 10.2         | 10.7            | 10.1               | 10.2         | 10.2        |

# Chapter 6

## ENVIRONMENTAL POLICY COOPERATION AND TRADE

### The Case of Symmetric Regions and Imperfect Competition

*“There is no free lunch in pollution control”*

Claus Conrad

#### 6.1 Introduction

Effective policy cooperation requires an understanding of how the relative size of cooperating partners influences policy outcomes. This is particularly important because the distribution of the regulatory burden is a decisive factor in deciding any type of regulatory action. In the preceding chapter, I demonstrated that policy impacts in the larger region, the EU, were stronger in the presence of real wage rigidities. In addition, on average, sectors in the smaller region, Canada, were more sensitive to policy shocks. Moreover, free trade improved the EU's responses to coordinated environmental taxes. In this chapter, I extend the analysis to consider trade and collective environmental taxes between two symmetric regions. The objective of this chapter is to investigate whether policy responses are different when symmetric regions engage in joint regulatory action. To this end, I apply the extended model presented in chapter 5 to NAFTA-EU trade. The two regions account for two thirds of global economic activity. For this reason, joint regulatory policy in the two regions can potentially affect non-participating regions.

I find that the effects of joint environmental taxes between two symmetric regions are smaller. In the case of NAFTA, results negligible. Interestingly, the unregulated region, the ROW, is more responsive to policy changes in the EU and NAFTA. The analysis of

market structure changes reveals that while aggregate output effects in the two symmetric regions are negligible, changes in market structure are more pronounced. The latter effect in part, explains the muted regulatory responses. Market structure results reveal that competitiveness changes can occur when environmental taxes are harmonized because joint regulatory taxes lead to the relocation of resources between to and from scale efficient sectors, and affect firm level markups. Further, results suggest that the interaction between free trade and market structure results in perverse welfare effects. Overall, while output effects under the symmetric assumption are lower, market structure is an important determinant of regulatory policy outcomes.

The literature on trade linked regulatory policy is extensive but mainly theoretical. As discussed in chapter 2, the common theme among these studies suggests that free trade can improve regulatory outcomes. In most of these studies the assumption of symmetry assumption is often used for analytical convenience Barrett (2003). It does however have empirical relevance especially when the issue of linking environmental policy to international trade cooperation is considered. Cheikbossian (2010) contends that the degree asymmetry and trans-boundary pollution affects a regions strategic incentives and the choice to commit to regulatory policy. Further, interaction between market structure and policy cooperation are important considerations in designing effective environmental policy (Vlassis, 2012). More importantly, a comparison between asymmetric and symmetric regions is warranted in the presence of strategic motives. Strategic incentives make it impossible for regions to enjoy the benefits of free trade in the absence of environmental policy (Kennedy, 1994).

Support for environmental policy cooperation derives from the concern that the uneven application of environmental taxes can result in competitiveness losses, especially when capital is mobile. For instance, when a trading region applies a relatively higher tax vis a vis its trading partner, relatively higher production costs have the potential of lowering the return to capital. If wages are endogenous, the consequent fall in capital can have adverse employment effects. Notwithstanding, total costs associated with harmonization differ across countries. In fact, the distribution of regulatory costs differs even when countries are symmetric. For instance, Horstmann and Markusen (1992) and Krugman (1992), note that

trade changes can occur even when trading partners are identical in all aspects. Different regulatory costs can cultivate incentives to manipulate other prices to cushion the regulatory costs.

Studies on joint policy between symmetric regions suggest that cooperative policy is mutually beneficial. For instance, Behrens et al.(2007) explain that harmonization encourages efficiency when initial taxes across countries differ. According to Keen et al.(2002), when competition between two symmetric regions is imperfect, harmonization always makes at least one region better off. Likewise, Behrens et al. finds that harmonization under imperfect competition is potentially welfare-improving. In contrast, MacAusland (2005) explains that when political preferences are considered, harmonizing regulatory policies can reduce global welfare and increase pollution, even when regions are identical. Nevertheless, almost all these conclusions derive from theoretical studies.

The preceding discussion yields three important insights. First, trade can potentially improve collective regulatory policy outcomes. Second, competitiveness concerns can motivate policy makers to use environmental policy for strategic purposes when trade policy tools are unavailable, hence, the need for collective regulatory interventions. Third, harmonization of environmental taxes can be mutually beneficial. In fact, Kennedy (1994) notes that benefits of free trade cannot be realized without policy cooperation on environmental externalities. For this reason, this paper seeks to answer the following questions: (a) Do conclusions about the benefits of free trade hold when trading regions are symmetric? (b) Does the regulatory approach matter? (c) Does symmetry between trading regions affect the way market structure responds to joint policy? and (d) Do labour market characteristics matter?

This chapter makes the following contributions (a) it quantifies and compares the effects of policy harmonization and coordination of environmental taxes when symmetric regions compete in imperfectly competitive market. Second, it investigates the validity of strategic incentive when regions are symmetric by simulating effects of below optimal, optimal and above optimal corrective taxes on polluting intermediates. Third, it examines whether labor

market considerations affect regulatory outcomes. Finally, it investigates whether regulatory policy affects market structure, given that the global market shares are evenly distributed across the three regions considered in this chapter.

The chapter is organized as follows: section 6.2 discusses the model extensions. Section 6.3 provides the justification for the case application and discusses chapter specific data. Simulation results and analysis are presented in section 6.4. Then the chapter concludes with section 6.5.

## **6.2 Model Extension**

As in the previous chapter, I consider a static Cournot Computable General Equilibrium (CGE) model with endogenous market structure and Increasing Returns to Scale (IRTS). As an extension, I relax the assumption of asymmetry between trading partners. Essentially, as a departure from the asymmetric case, the global consumer base is almost evenly distributed across the three regions. Table 6.1 displays the distribution of sectoral shares across the three regions. Similarly, the differences in the baseline taxes are small; the harmonized taxes are less skewed towards one region.

## **6.3 Application, Chapter Specific Data and Calibration**

The model is applied to trade between the North American Free Trade Agreement (NAFTA) region and the EU. This analysis brings together two of the world's largest Free Trade Areas accountable for two-thirds of global output and a combined market of USD 40.6 Trillion. On average NAFTA accounts for 30 percent of global output, while the combined output for the EU and NAFTA regions account for approximately 60 percent of global output. It follows therefore, that regulatory changes in the two regions have important implications for economic activity in the rest of the world. More importantly, compared to the EU,

environmental taxes in NAFTA are not as widely applied. Metcalfe (2008) states that environmental taxes account for only 0.9 and 0.8 percent of the US and Mexico's GDP compared to an average of 3 percent in the EU. In the US 94 percent of environmental taxes are taxes on motor fuels (p.3). This analysis is therefore timely because it offers a "what if" perspective on US and NAFTA's responses to a broader application of environmental taxes.<sup>1</sup>

Table 6.1: Sectoral Shares by Region

| Sector | NAFTA | EU  | ROW |
|--------|-------|-----|-----|
| AGF    | 0.2   | 0.2 | 0.5 |
| COAL   | 0.4   | 0.1 | 0.6 |
| PET    | 0.2   | 0.2 | 0.7 |
| GAS    | 0.3   | 0.1 | 0.6 |
| MMM    | 0.3   | 0.3 | 0.5 |
| CPR    | 0.3   | 0.3 | 0.4 |
| PPW    | 0.4   | 0.3 | 0.3 |
| MNFS   | 0.3   | 0.3 | 0.5 |
| OPT    | 0.3   | 0.3 | 0.4 |
| SVCS   | 0.4   | 0.3 | 0.3 |

The GTAP database is aggregated into three regions, NAFTA, the EU -27 and the ROW.<sup>2</sup> The sectors are Agriculture and Food (AGF), Coal, Petroleum products (PET), Gas, Metals and Minerals (MMM), Chemicals, Plastics and Rubber (CPR), Pulp, Paper and Wood (PPW), Manufactures (MNCS), Transport(OPT) and Services (SVCS). Primary factors include unskilled and skilled labor, capital and resources (land plus all other resources). Table 6.1 summarizes the distribution of market shares across the three regions. At the sectoral level, the US accounts for a larger share of the production of polluting inputs.

<sup>1</sup>US accounts for 85 percent of NAFTA's economic activity (<http://www.naftanow.org/facts>).

<sup>2</sup>The accession of the 28th country came after simulations where completed.

In particular, it accounts for 36 and 31 percent of coal and natural gas. Further, its share in chemicals and pulp and paper industries are 30 and 40 percent respectively. The latter is the largest among the regions. Similarly, the EU accounts for one-third of chemical, pulp and paper and manufacturing output.

Table 6.2 shows the baseline environmental taxes. The US has higher optimal levies compared to the EU for all classes of intermediates. This difference is attributed to the lower marginal cost of public funds and differences in marginal external damages. In the baseline equilibrium, emission levies are calculated endogenously using emission coefficients estimated by the author using time series data from EUROSTAT, the US Environmental Protection Agency (EPA), the US Department of Energy and the US Bureau of Economic Analysis (BEA). Data on the Marginal Cost of Public Funds (MCPF) is obtained from Barrios, Pycroft and Saveyn (2013), Dixon, Honkaurkia and Rimmer (2012) and Auriol and Walters (2012).

Table 6.2: Symmetric Case Baseline Second Best Environmental Taxes (\$)

| Input | NAFTA | EU    | ROW   |
|-------|-------|-------|-------|
| COAL  | 15.99 | 7.18  | 24.32 |
| PET   | 20.61 | 12.49 | 42.33 |
| GAS   | 17.6  | 7.35  | 28.57 |
| MMM   | 2.45  | 1.82  | 3.85  |
| CPR   | 2.36  | 1.71  | 2.96  |
| PPW   | 19.55 | 14.69 | 26.35 |

Table 6.2 shows that NAFTA is a relatively high tax region compared to its trading partner. Taxes on energy based intermediates are twice the size of the EU's. However, for the ROW, are in excess of three times of the EU's. This implies that counterfactual simulations that remove taxes in the ROW will confer sizable relative cost advantages on the region.

## 6.4 Simulation Results and Discussion

In the baseline equilibrium, region specific second best environmental taxes on polluting inputs are applied to all polluting intermediates. The following subsections present results of counterfactual simulations. Expressly, the results are in two categories. First, I consider regulatory outcomes when the real wage of the unskilled labor category is fixed. Second, I relax the constraint on the labor market to analyze policy effects when wages are endogenous.

### 6.4.1 Effects of Collective Environmental Taxes in the Presence of Real Wage Rigidities

#### Output Effects under Fixed Wage Closure

Output effects of coordinated and harmonized taxes in the presence of real wage rigidities when symmetric regions compete in imperfectly competitive markets (SY\_IC) are presented in tables 6.3. Three insights can be derived from Table 6.3. First, in the presence of real wage rigidities, output effects of coordinated levies in the two regulating regions are small. NAFTA in particular has insignificant output changes in almost all policy scenarios. Second, apart from the above optimal tax cum free trade policy, free trade has no significant effect on regulatory outcomes. Third, policy shocks induce notable output changes in the unregulated region. Further, coordinated environmental taxes have negligible effects on the unskilled labor category.

According to Table 6.3, coordinated taxes in the absence of free trade have minor effects of both the EU and NAFTA, but cause sizeable changes in the output of the unregulated region. For instance, when the EU and NAFTA maintain optimal taxes while intermediates in the ROW remain unregulated, the ROW's output rises by 2.1 percent. This result derives mainly from the direct effects of relatively lower production costs on output. The region experiences cost advantages from a zero tax stance because its baseline environmental taxes are significantly higher than both the EU and NAFTA. If instead border taxes are zero,

all regions generally experience negligible output changes save for the above optimal tax. Under the above optimal cum free trade coordinated tax scheme, the EU's aggregate output is 1.4 percent higher than baseline. The direct effect of increased intermediate input prices is unambiguous as optimizing firms reduce output in response to higher production costs. Notwithstanding, the effects of the above optimal cum free trade policy scenario are difficult to isolate. For instance, the effect of input prices on final commodities depends on the net effect of the upward cost adjustment due to the above optimal tax shock and the downward adjustment associated with the removal of border taxes. At the aggregate level, results suggest that the price of savings falls. Because of this, the savings portfolio in the regional bank falls, as a consequence investment and the equilibrium level of capital decline. In terms of induced effects, the fall in output is in part due to increased market power in the petroleum products as evidenced in a 2.4 and 16 percent rise in market share and firm level markups respectively.

Table 6.3: Output Effects under the Fixed Wage Closure: SY\_IC (% Change)

|        |              | Coordinated Taxes |        |      | Harmonized Taxes |        |      |
|--------|--------------|-------------------|--------|------|------------------|--------|------|
|        | Levy         |                   | NO FTA | FTA  |                  | NO FTA | FTA  |
| Region | Initial      | New               | GDP    | GDP  | New              | GDP    | GDP  |
| Canada | $\tau_{opt}$ | $\tau_E = 0$      | 0.0    | 0.0  | $\tau_{LB}$      | 0.1    | -0.1 |
| EU     | $\tau_{opt}$ | $\tau_E = 0$      | -0.6   | -0.7 | $\tau_{LB}$      | -0.6   | 2.0  |
| ROW    | $\tau_{opt}$ | 0.0               | 1.5    | 1.0  | 0.0              | 0.1    | 0.9  |
| Canada | $\tau_{opt}$ | $\tau_{opt}$      | 0.0    | -0.1 | $\tau_{WTD}$     | 0.3    | 0.0  |
| EU     | $\tau_{opt}$ | $\tau_{opt}$      | -0.1   | -0.1 | $\tau_{WTD}$     | -0.7   | -0.5 |
| ROW    | $\tau_{opt}$ | 0.0               | 2.1    | 4.7  | 0.0              | 0.0    | 4.2  |
| Canada | $\tau_{opt}$ | $\tau_E + \$10$   | 0.0    | -0.2 | $\tau_{UB}$      | 0.0    | 0.0  |
| EU     | $\tau_{opt}$ | $\tau_E + \$10$   | -0.2   | 1.4  | $\tau_{UB}$      | 0.7    | 0.9  |
| ROW    | $\tau_{opt}$ | 0.0               | -0.4   | -0.1 | 0.0              | 2.1    | -0.3 |

In the case of NAFTA, negligible output effects are likely due to the shocks not being

large enough to affect costs of production and output. This lends support to Jaffe et al. (1995) who conclude that regulatory policy has negligible effects on the US's GDP because abatement costs account for a very small fraction of total costs. Given that the US accounts for 85 percent of NAFTA's aggregate output ([http://www.naftanow.org/default\\_en.asp](http://www.naftanow.org/default_en.asp)), regulatory outcomes of the US determine the regions overall response. Nevertheless, regulatory taxes have significant structural effects on the region's sectors. Changes in market structure are also likely to dampen the direct effects of joint regulatory policy on the region.

Harmonized environmental taxes have a similar effect on output. The results in Table 6.3 suggest that, in the presence of real wage rigidities, costs of harmonizing environmental taxes in between symmetric regions are negligible. As in the coordinated case, the ROW is more responsive to regulatory changes in NAFTA and the EU. Under free trade, the lower and upper bound harmonized taxes schemes results in 2 and 0.9 percent higher than baseline output respectively. Under both tax scenarios, the removal of border taxes reduces the prices of traded goods relative to the ROW, inducing a rise in domestic production. Moreover, when environmental taxes are minimum, output rises by 2 percent because free trade causes a reallocation of scale resources to manufacturing and services. Expansion of manufacturing results in a 7.8 percent rise in the investment component of GDP. In contrast, the 0.9 percent rise in output under the upper bound tax scheme derives from a 4.2 percent rise in equilibrium capital resulting from a rise in scale efficiencies in coal, petroleum and gas.<sup>3</sup> Further, petroleum market share and markups rise 0.8 and 9 percent respectively. While the rise in market share and mark-ups indicates increased industrial concentration, advantages of increased scale economies result in higher production and as a consequence, investment. On the external front, the small current account deficit reinforces investment.

### **Trade and Competitiveness Effects under Fixed Wage Closure**

The existence of intra-industry trade makes it difficult to ascertain the direction of trade. According to Horstmann and Markusen(1992), the analysis of trade is rather complex, and

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<sup>3</sup>the EU's energy sectors are capital intensive.

distribution of gains can be indeterminate. Therefore, to understand changes comparative advantage, relative gains are analyzed within the context of the changing scale economies and composition of trade. More importantly, issues of competitive advantage are central to the strategic policy debate. In this section, I consider how both comparative and competitive advantage changes in response to regulatory choices. Further, I also examine whether results support the “pro-concentration motive” advanced by van Long and Soubeyran (2005).

The results suggest that the sensitivity of aggregate trade flows to regulatory choices is low. This might seem counter-intuitive; however, Horstmann and Markusen (1992) and Krugman (1992) note that in the presence of imperfect competition, trade changes can occur even if trading partners are identical in all aspects. While changes in aggregate trade flows are small, the results reveal that harmonizes taxes divert trade away from the non-regulated region even in the absence of free trade. Sectoral shifts are stronger confirming earlier studies by van Beers and van den Berg (1997). In addition, NAFTA’s sectors are more sensitive to regulatory choices than the EU’s. NAFTA’s sectoral changes essentially imply that the sectoral output elasticities are higher. This observation lends support to Tobey (1990), van Beers, and van den Berg (1997). According to the results, zero taxes in the absence of free trade result in a negative trade balance for NAFTA and a gain for the EU. Under free trade, changes in the trade balance are stronger; NAFTA’s losses are significantly larger. Further, when environmental taxes are above optimal, NAFTA experiences a minor fall in net exports while the EU gains. Under free trade both regions gains, while the ROW’s trade balance worsens. The latter result suggests that, while trade flows in both regions are more sensitive to changes in border taxes, free trade between the two regions affords more benefits to the EU. However, these are just partial insights because trade outcomes are highly sensitive to trade parameters.

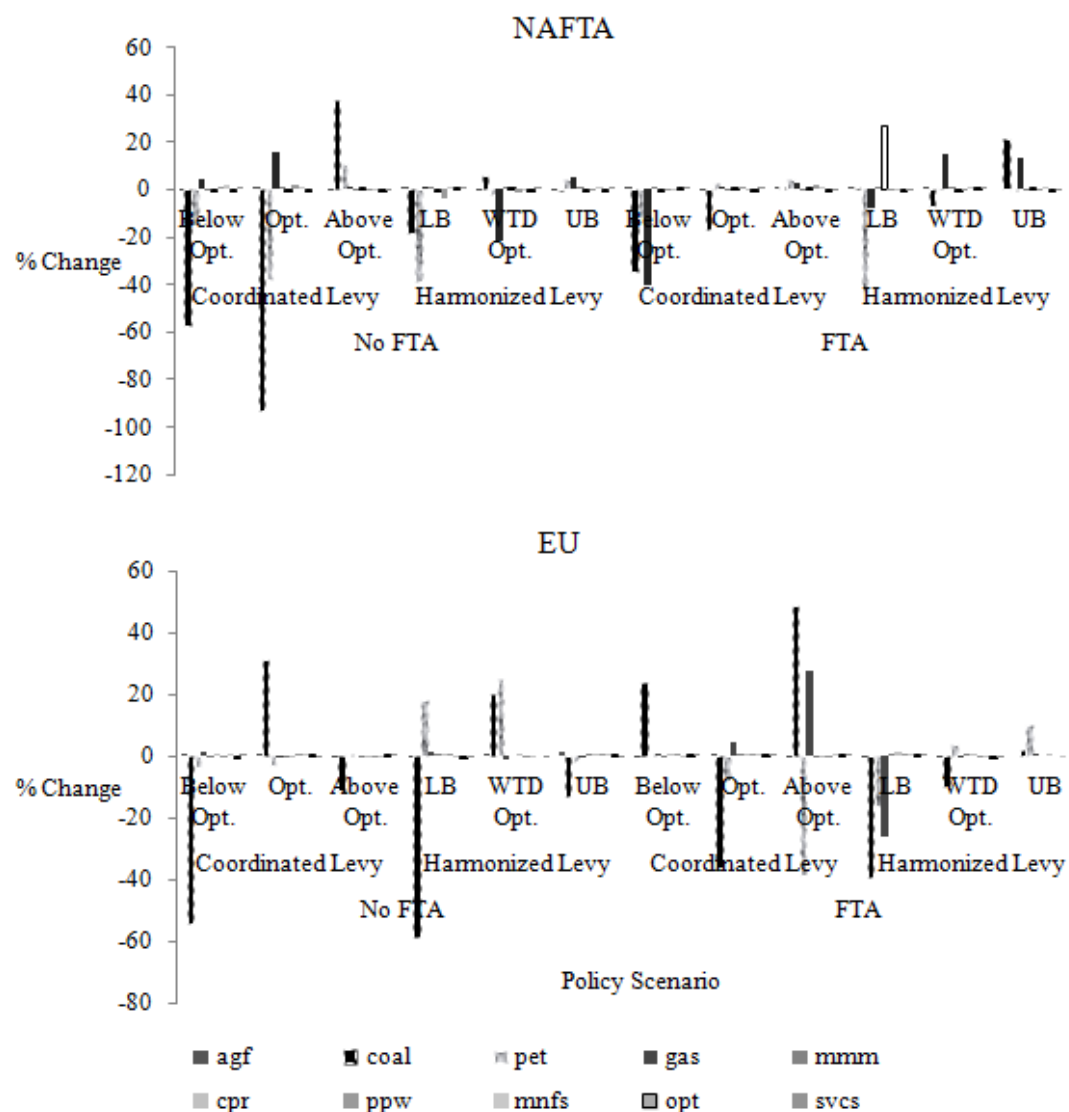
Contrary to common perceptions, harmonized taxes can affect competitiveness.<sup>4</sup> Changes in competitiveness occur because market structural responses to joint regulatory policy differ across regions. For this reason, it is possible to competitiveness losses to occur under a

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<sup>4</sup>This result is important because competitiveness concerns feature prominently in joint regulatory policy discussions.

less stringent policy stance. Figure 6.1 illustrates changes in firm level markups in NAFTA and the EU. While Figure 6.1 reveal that coal is the most policy sensitive sector in both regions, the effects of policy on the coal sector are more pronounced in the EU. Further, a close examination of Figure 6.1 reveals that almost all of NAFTA's sectors are responsive to joint taxes on polluting intermediates. In contrast, taxes in the EU mainly affect the three energy sectors: coal, petroleum and gas.

Figure 6.1: Markup Changes under Fixed Wage Closure - SY\_IC (%)



Starting with zero coordinated taxes in the absence of free trade, the results suggest that the rise in competition resulting from lower production costs reduce competitiveness of firms

in the coal and petroleum across all three regions, including the ROW. Specifically, Figure 6.1 shows that markups in the coal sector fall by 58 and 55 percent in NAFTA and the EU, while markups in the petroleum sector fall by 14.8 and 3.5 percent respectively. Despite the contraction in markups in the ROW, the losses are insignificant. Moreover, coal and petroleum sectors experience a fall in scale efficiencies resulting from the entry of new firms. Interestingly, industrial concentration and competitiveness rises in the gas sector most likely due to a shift in production to cheaper energy goods like coal. Likewise, competitiveness of firms in the manufacturing sector increases across all three regions. While free trade reduces the competitiveness of all three energy-producing sectors in NAFTA, the EU's energy goods producing sectors become more competitive and concentrated. Because the EU is a net importer of all three energy classes, a fall in the cost of imports likely shifts production to more energy abundant regions.<sup>5</sup> The fall in domestic energy production causes the firms to exit energy sectors, hence, the increased concentration in the EU's energy sectors.

For positive level of environmental taxes, NAFTA's coal, petroleum and chemical sectors lose both comparative and competitive advantage under the optimal tax no free trade scheme. Firm level markups fall by 60, 10 and 1 percent in the three sectors respectively. Correspondingly, coal and petroleum market shares fall by 9.2 and 4.7 percent. In contrast, firms in the gas and metal sectors enjoy scale efficiency gains and an 11 and 1.3 percent rise in markups. Under free trade, the regions market share in coal, petroleum and gas sectors rise by 0.5, 3 and 1 percent. Similarly, NAFTA's manufacturing sector experiences a loss in both competitive and comparative advantages. If instead, regulatory taxes are above optimal, Figure 6.1 reveals that coal, petroleum and gas sectors become more competitive as markups rise by 37, 10 and 1 percent. Further, the stringent policy stance results in significant crowding in of scale economies in the coal and petroleum sectors. Metals, and non-regulated manufacturing and services experience minor losses in scale efficiencies. Efficiency gains in the energy sectors offset direct effects of higher production costs, hence the insignificant change in aggregate output. While free trade generates similar effect in the three-energy sector, competitiveness changes are smaller because the lower costs of imported

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<sup>5</sup>According to EUROSTAT, the EU imported 53.4 percent of all its energy requirements in 2012.

inputs partially offset higher production costs associated with the above optimal regulatory taxes. Under free trade, gas markups rise by 4.2, 3 and 2 percent. Further, changes in scale economies are minor.

Market structure dynamics in the EU are mainly limited to the three energy sectors. In general, the firms in the EU's petroleum sector gain competitiveness under the harmonized environmental taxes. This change is more significant when harmonized taxes combined with free trade. In the coal sector, a more stringent regulatory stance applied in the absence of free trade results in reduced competitiveness. In contrast, free trade results in a modest gain in markup. For both sectors, the upper bound environmental taxes combined with free trade seem to confirm van Long and Soubeyran's (2005) conclusion that above optimal taxes at firm level selectively penalize inefficient firms. The key difference here is that environmental taxes are levied on polluting intermediates. Effects of coordinated levies are more pronounced in the absence of free trade. Firms in the coal sector experience a 30.3 percent rise in markups, compared to the 17 percent fall in the petroleum sector. For the former, the result suggests that the higher costs induce firms to exit the sector and consequently, the sector becomes more concentration. In contrast, the result for petroleum is less intuitive; markups fall but economies of scale rise. In general, the petroleum sectors response to policy regardless of the trade policy is anti-competitive, but secures high rents for the region.

Unlike the EU, minimum harmonized taxes have deeper structural effects in NAFTA. Instance, under the assumption of free trade, the coal, petroleum and gas sectors experience a rise a market share of 1.1, 1.4 and 1 percent. However, the gas sector loses both comparative and competitive advantage. In particular, firm level markups fall by 13 percent, and the CDR ratio falls significantly. The loss in markups is expected because the move from optimal baseline environmental taxes to the minimum scheme reduces NAFTA's tax on gas from \$17.6 to \$7.35. The fall in the user cost of gas induces firms to enter the gas industry, thus reducing scale economies. Likewise, competitiveness falls because increased competition reduces markups. Free trade cushions but does not offset the sectors competitiveness losses. Firm-level markups in the gas sector fall by 9 percent compared to 13 percent in the

absence of free trade. Further, under free trade, manufacturing, metals and pulp and paper sectors become more competitive. Other than these changes, all other shifts are limited to the coal, gas and petroleum sectors.

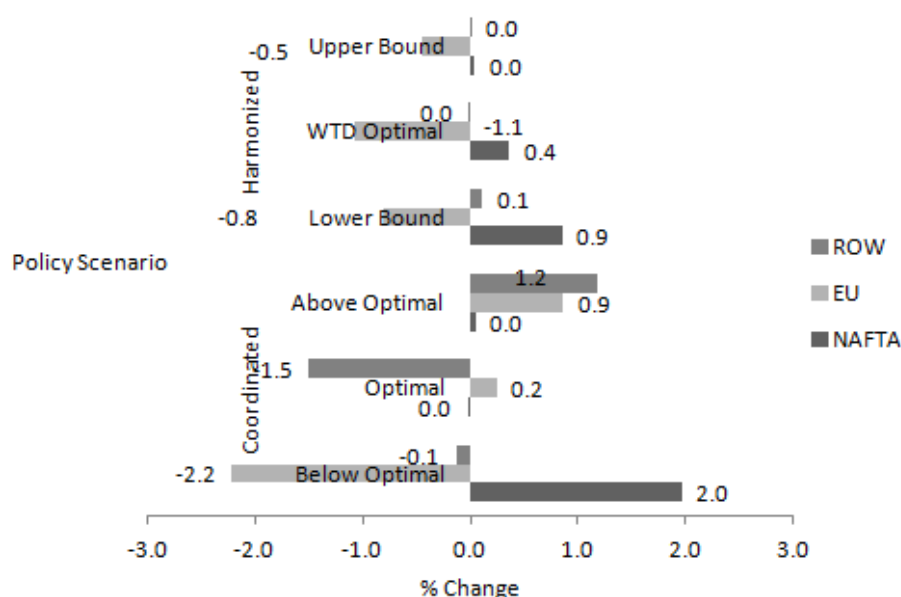
While it is difficult to completely isolate the shock propagation mechanism generating these results, gains in market share at upper bound tax levels are possible. This is because the upper bound harmonized environmental tax scheme affords NAFTA relative cost advantages vis a vis the EU. These cost advantages enjoyed by incumbent firms can serve as an entry deterrent under both wage assumptions. Applied to NAFTA, this result supports Behrens et al.'s (2007) proposition that a harmonized commodity tax should be set to equal the upper bound level. Importantly, harmonized taxes in the presence of real wage rigidities increase the competitiveness of firms in the EU's petroleum sector.

### **Welfare Effects under Fixed Wage Closure**

This section discusses the welfare effects of collective regulatory taxes between two symmetric regions in the presence of real wage rigidities. Figure 6.2 illustrates welfare effects of the various policy scenarios in the absence of free trade. The figure reveals that positive coordinated taxes result in net welfare gains for the EU while the move from optimal to zero taxes reduces welfare by 2.2. The 2.2 percent fall in welfare is the net result of a 0.6 percent fall in aggregate output and a 17 percent rise in pollution. The above optimal tax results in minor gains in welfare for both regions. While trivial, the outcome is consistent with van Long and Soubeyran's (2005) efficiency hypothesis. Higher welfare derives mainly from reduction in pollution illustrated Table 6.5 of appendix 6.A. According to figure 6.2, the EU's welfare under the harmonized schemes is lower than the baseline. Nevertheless, the losses are less than 1 percent. This result presents a departure from findings by Behrens et al. (2007) and Keen et al. (2002) who contend that a harmonized scheme between symmetric regions has superior welfare effects. It is worth noting that the two studies consider the harmonization of commodity taxes. Further, as a departure from Behrens et al. and Keen et al., my analysis assumes the presence of real wage unemployment.

Figure 6.2 shows that NAFTA's welfare changes in the presence of real wage rigidities and no free trade. The result suggest that NAFTA's welfare effects range from 0.0 to 2.0 per cent. Essentially, NAFTA's regulatory outcomes in the absence of free trade are favourable. While gains from positive coordinated tax are minor, the region's welfare increases by 2 percent when regulatory taxes are zero. Welfare under a zero tax scheme rises despite the 23 percent rise in pollution because lower oligopolistic prices the increase utility. The latter exceeds the disutility from higher pollution. Under the above optimal scheme, higher welfare derives mainly from a 10 percent fall in pollution. Changes in aggregate output are insignificant because market structure changes partially offset higher costs associated with the stringent regulatory policy. Unlike the EU, NAFTA's welfare under the harmonized scheme is higher than the baseline level. The most significant gain occurs under the lower bound tax scheme (0.9 percent). Welfare rises despite the negligible 1 percent rise in output and the 15 percent rise in pollution because relatively lower prices boost regional utility.

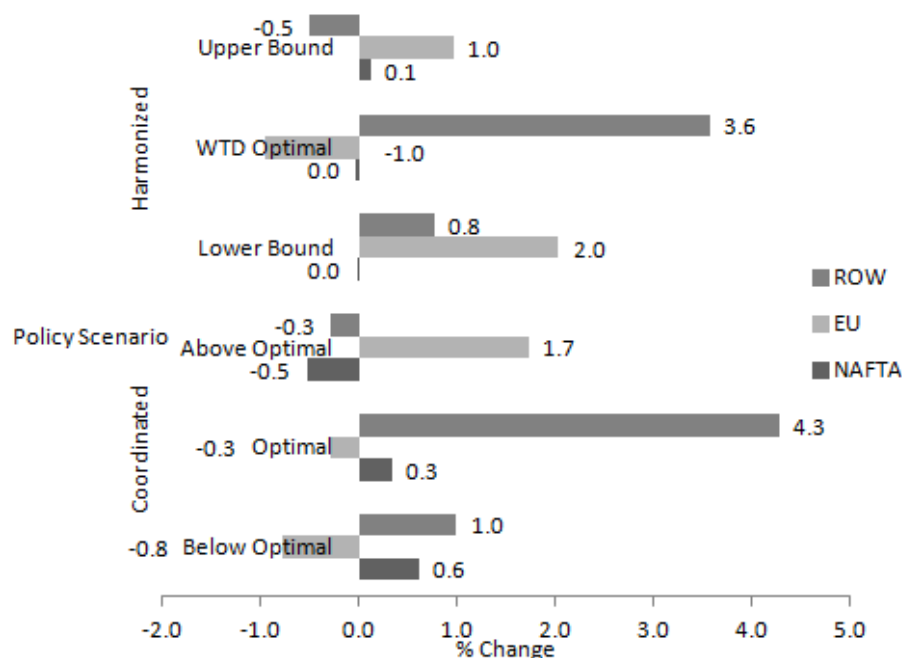
Figure 6.2: Welfare Effects under Fixed wage No FTA Closure - SY\_IC (% Change)



The introduction of free trade dampens the effects of zero environmental taxes for both regions. Nevertheless, Figure 6.3 shows that free trade only partially offsets the losses for the EU. Optimal coordinated levies applied in the absence of free trade result in modest welfare gains in the NAFTA region and small losses in the EU. In the absence of output

changes, NAFTA's gains are in part due to a marginal decline in pollution and increased competition in the energy sector, which drives oligopolistic energy prices down. In the case of the EU, while the coal sector becomes competitive this effect is not large enough to offset the combined direct losses from output and increased market power in the petroleum sector. This is because coal makes up only 0.07 percent of value added. Interestingly, the ROW's 1.5 percent losses in the absence of free trade is more than offset by the introduction of free trade between NAFTA and the EU. Expressly, the ROW's welfare rises by 4.3 percent. Higher welfare derives mainly from a 4.7 percent rise in aggregate output.

Figure 6.3: Welfare Effects under Fixed wage FTA Closure - SY\_IC (% Change)



Gains from free trade more than offset the EU's losses from the above optimal tax. This result is in part due to higher output (1.4 percent) associated with the crowding in scale efficiencies and increased concentration in the coal, gas and manufacturing sectors. In addition, the gain in welfare derives from an improvement in air quality resulting from a 17 percent reduction in pollution. Given that benefits of free trade equal direct transfers (Turunen-Red and Woodland), this result lends support to Katsoulacos and Xepapadeas (1995) who explain that a lump sum transfer that increases market concentration can be welfare improving. In contrast, while NAFTA's pollution falls by 10 under the same policy

scheme, free trade exacerbates welfare loss for NAFTA. The loss is however inconsequential. The worsening of welfare under free trade is due to a modest fall in output and a worsening trade balance.

Results in Figure 6.2 reveal that harmonized environmental taxes exert welfare costs on the EU. When trade is liberalized, Figure 6.3 reveals that free trade more than offsets the EU's welfare losses from lower and upper bound taxes. Specifically, welfare rises by 2 and 1 percent under the two tax schemes respectively. In contrast, free trade has an insignificant effect on welfare resulting from a weighted optimal regulatory scheme. The region gains welfare because free trade increases efficiencies in the EU's energy sectors. Essentially, because the EU is a net importer of energy products, free trade increases energy imports. Higher import competition drives out less efficient firms and increases sectoral concentration. Both markups and scale economies rise and consequently welfare increases because of a rise in output and oligopolistic rents. Further, as indicated in Table 6.4 of appendix 6.A, pollution falls by 2.5 and 5.8 percent under the lower and upper bound regulatory scheme.

Unlike the EU, NAFTA's welfare changes are trivial. While negligible, welfare effects under free trade indicate that the removal of border taxes reduces gains from the lower bound and weighted optimal schemes applied in the absence of free trade. An examination of the pollution changes presented in Table 6.3 and 6.4 of appendix 6.A reveals that pollution increase under the lower bound tax scheme is lower when trade is liberalized. For this reason, the lower welfare derives mainly from market structure dynamics and the worsening trade balance.

#### **6.4.2 Effects of Collective Environmental Taxes in the Presence of Flexible Wages**

In this section, I relax the labour market constraint to demonstrate how outcomes of joint regulatory policy differ when the economy is at full employment. The removal of the labour market constraint allows increases the substitution possibilities available to firms. Further,

the flexibility assumption implies that part of the regulatory pulse is absorbed via the adjustment in wages for both labour categories.

### Output Effects under the Flexible Wage Closure

Table 6.4 presents output effects of coordinated and harmonized environmental taxes when wages are flexible. The results in Table 6.4 reveal that when wages are flexible, output effects of joint policy on NAFTA and the ROW are small. Further, compared to changes under the fixed wage closure, the EU's regulatory costs are low. Under the coordinated tax scheme, output effects range from  $-0.2$  to  $1.8$  percent for NAFTA,  $-0.8$  to  $2.4$  percent in the EU, and  $-3.6$  to  $0.5$  percent in the ROW.

Table 6.4: Output Effects under the Flexible Wage Closure: SY\_IC (% Change)

|        |              | Coordinated E-Taxes |        |      | Harmonized E-Taxes |        |      |
|--------|--------------|---------------------|--------|------|--------------------|--------|------|
|        | Levy         |                     | NO FTA | FTA  |                    | NO FTA | FTA  |
| Region | Initial      | New                 | GDP    | GDP  | New                | GDP    | GDP  |
| NAFTA  | $\tau_{opt}$ | $\tau_E = 0$        | 0.0    | -0.2 | $\tau_{LB}$        | -0.1   | 0.0  |
| EU     | $\tau_{opt}$ | $\tau_E = 0$        | 0.1    | 0.8  | $\tau_{LB}$        | -0.1   | 0.2  |
| ROW    | $\tau_{opt}$ | 0.0                 | 0.0    | -0.8 | 0.0                | 0.1    | -0.1 |
| NAFTA  | $\tau_{opt}$ | $\tau_{opt}$        | 1.8    | 0.0  | $\tau_{WTD}$       | 0.2    | -0.8 |
| EU     | $\tau_{opt}$ | $\tau_{opt}$        | 2.4    | -0.1 | $\tau_{WTD}$       | 0.1    | 1.1  |
| ROW    | $\tau_{opt}$ | 0.0                 | -3.6   | 0.1  | 0.0                | -0.2   | 0.3  |
| NAFTA  | $\tau_{opt}$ | $\tau_E + \$10$     | 0.0    | 0.1  | $\tau_{UB}$        | 0.0    | 0.1  |
| EU     | $\tau_{opt}$ | $\tau_E + \$10$     | 0.0    | -0.8 | $\tau_{UB}$        | -0.1   | -1.5 |
| ROW    | $\tau_{opt}$ | 0.0                 | 0.0    | 0.5  | 0.0                | 0.0    | 1.0  |

According to Table 6.4, the most significant changes in output occur when optimal coordinated environmental taxes are applied independent of free trade. For NAFTA and the EU, output is 1.8 and 2.8 percent higher than the baseline. In contrast, the ROW's output falls by 3.6 despite the relative cost advantage of a zero tax regulatory stance. In

the presence of imperfect competition and endogenous market structure, this is a likely outcome. First, higher production costs in NAFTA and the EU vis a vis the ROW cause a reallocation of resources from less scale efficient sectors. Second, the remaining firms are likely to be more efficient. For this reason, the direct effect of relatively higher production costs is more than offset by efficiency gains due to induced changes in market structure. While this effect is likely to be stronger under the stringent above optimal tax policy, the net output effect can be lower because increased market concentration increases market power and consequently the distortionary effect of imperfect competition. Output effects are zero for NAFTA and the EU because the latter effect offsets the positive output gains from larger scale economies.

Table 6.4 reveals that under free trade regulatory costs are minor. However, close inspection also shows that free trade reverses gains for both regulating regions when taxes are optimal, and imposes a 0.8 percent cost on the EU, when taxes are above optimal. Revisiting Katsoulacos and Xepapadeas (1995), results in this section reveal that when wages are flexible and symmetric regions compete in imperfectly competitive markets with endogenous market structure, indirect transfers proxied by free trade can worsen regulatory outcomes. This is because by reducing costs of production, free trade makes markets less concentrated.

The last two columns of Table 6.4 shows output effects of harmonized taxes under no free trade and free trade assumptions. As is the coordinated case, output effects are minor. This is particularly true when environmental taxes are harmonized independent of free trade. Here again, market structure changes offset the costs of regulatory policy. For NAFTA, this result carries forward to the free trade scenario. In contrast, free trade has a positive effect on the EU's output when the minimum and weighted optimal taxes are applied. Compared to harmonized taxes under the fixed wage closure, upper bound taxes combined with free trade result in a 1.5 percent reduction in aggregate output. The latter result is due in part to increased integration of energy and manufacturing sectors as gains in scale advantages result in higher output.

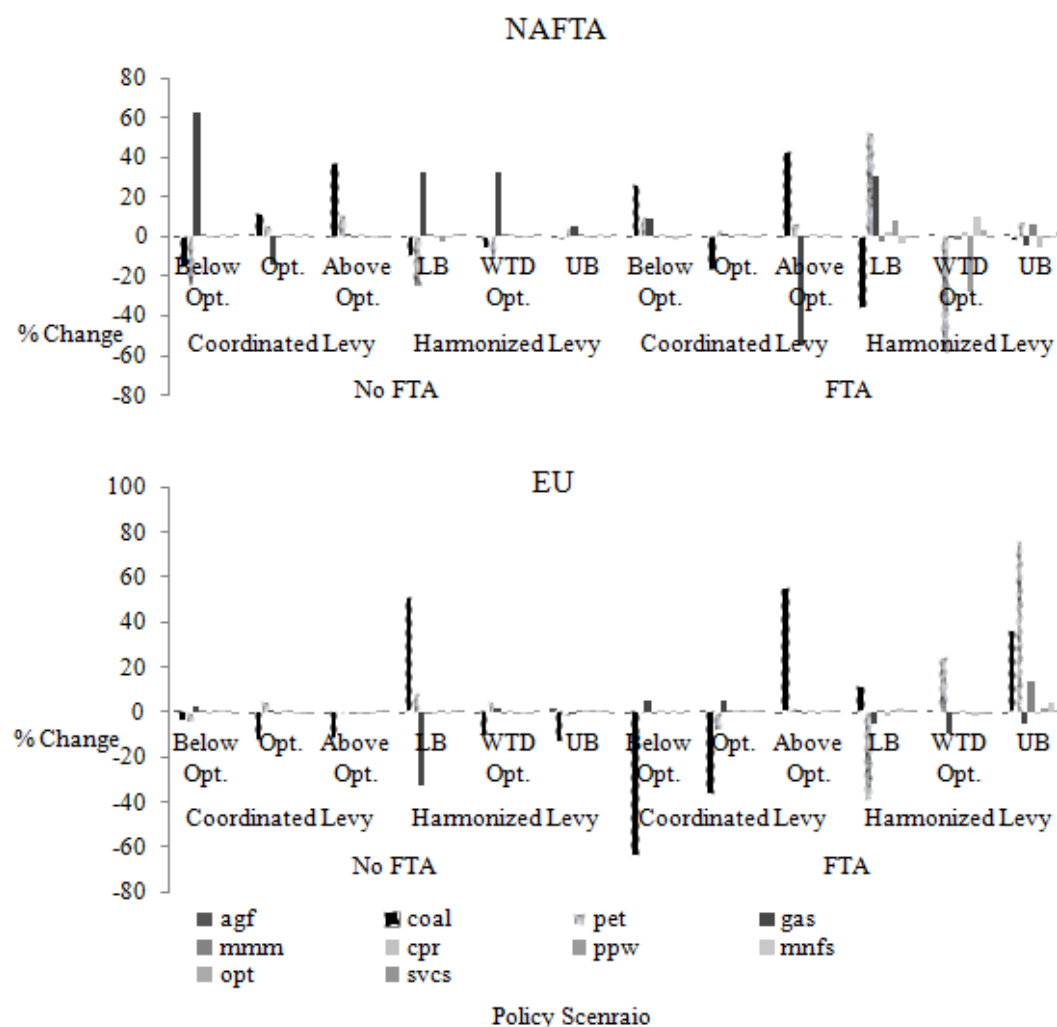
## Trade and Competitiveness Effects under the Flexible Wage Closure

When wages are fully flexible, the results show that on aggregate, trade volumes are not very sensitive to environmental taxes. The insensitivity of aggregate trade flows to regulatory policy is also observed in Low and Yeats (1992) and Tobey (1990). Ederington and Minier (2003) attribute this result to the exogenous specification of emission taxes. When taxes are endogenously determined, for instance via lobbying, trade flows are more responsive. Notwithstanding, sectoral flows are sensitive to regulatory choices. In the NAFTA region, nearly all sectors respond to policy changes, nevertheless, the most trade sensitive sectors are agriculture, coal, gas and manufacturing. The contribution of induced changes to net policy effects are mainly determined by changes in manufacturing. This result are consistent with van Beers and van der Berg (1997) who argue that sectoral characteristics have important implications for how trade and output responds to regulatory policy. For instance, they find that for resource based industries, no correlation exists between environmental stringency and trade flows, while the opposite is true for non resource based industries like chemicals and metals.

Figure 6.4 illustrates changes in firm level markups in response to joint policy when wages are fully flexible. A comparison between the upper (NAFTA) and lower (the EU) panels of Figure 6.4 reveals that NAFTA's sectors are more responsive to regulatory changes than the EU. In particular, firms in the three energy sectors (coal, petroleum and gas) experience sharp changes in competitiveness. Additionally, sectors producing non-regulated and regulated intermediates are responsive to policy. Changes in NAFTA suggest that when regulatory taxes are zero only the gas sector becomes more competitive under the no free trade scenario. If instead trade taxes are zero, all three energy sectors enjoy both scale efficiency gains and higher markups. According to the results, under the zero tax no free trade scheme, gas markups rise by 62 percent, while markups in coal and petroleum fall by 15.5 and 27.8 percent respectively. In the presence of free trade, gas markups only rise by 8.9 percent, while firms in the coal and petroleum sectors gain competitive advantage as markups rise by 26.4 and 10.4. Under the coordinated no free trade scheme, firms in

petroleum and the coal sectors experience a higher competitiveness as markups rise by 11.9 and 6.4 percent.

Figure 6.4: Markup Changes under Flexible Wage Closure - SY\_IC (%)



In the EU, the effects of coordinated taxes are mainly limited to the three energy sectors. The coal sector becomes less competitive when coordinated taxes are applied in the absence of free trade. Further, the sector experiences a significant fall in scale economies. According to the results, coal in the EU exhibits Giffen good characteristics. For this reason, higher demand for coal when environmental taxes are positive indicates a shift towards the consumption of a less expensive energy source. The combination of higher demand, entry and higher marginal costs deplete scale economies and firm level markups. In fact, for all regulatory tax schemes save lower bound taxes applied independent of free trade, the

competitiveness of the EU's coal sector falls. In contrast, the petroleum sector gains both competitive and comparative advantage when positive coordinated taxes are applied in the absence of free trade. According to Figure 6.4, the upper bound tax scenario affects almost all sectors. An upper bound tax scheme independent of free trade, results in competitiveness losses for all three energy sectors, and gains in metals, pulp and paper, and manufacturing.

Free trade magnifies competitiveness gains in metals, manufacturing and pulp and paper. Further, free trade reverses competitiveness losses in coal and petroleum. In the coal sector, a policy combining harmonized taxes with free trade results in gains in comparative and competitive advantages. The opposite is true for the EU's gas sector. While an increase in scale is associated with higher market power and lower output, the general decline in cost disadvantage ratios and markups results in a net expansion in coal production, resulting in the rise in coal production in the absence of free trade. In contrast, the petroleum sector experiences a fall in economies when coordinated taxes are applied in the absence of trade and an expansion when weighted and upper bound taxes are combined with free trade.

### **Welfare Effects under Flexible Wage Closure**

This section discusses welfare effects of joint regulatory policy when the economy is at full employment. The literature on joint taxes between symmetric regions seems to suggest that it is mutually beneficial. McAusland (2005) presents an alternative view. She argues that regulatory policy can have adverse welfare effects even when regions are symmetric. The results presented in this section suggest that in the absence of free trade welfare effects of harmonized taxes are negligible. Further, the results suggest that output and market structure effects account for the large proportion of the welfare changes. This is clearly observable when I consider pollution effects presented in Tables 6.6 and 6.7 of appendix 6.A.

Figure 6.5: Welfare Effects under Flexible Wage No FTA Closure - SY\_IC (% Change)

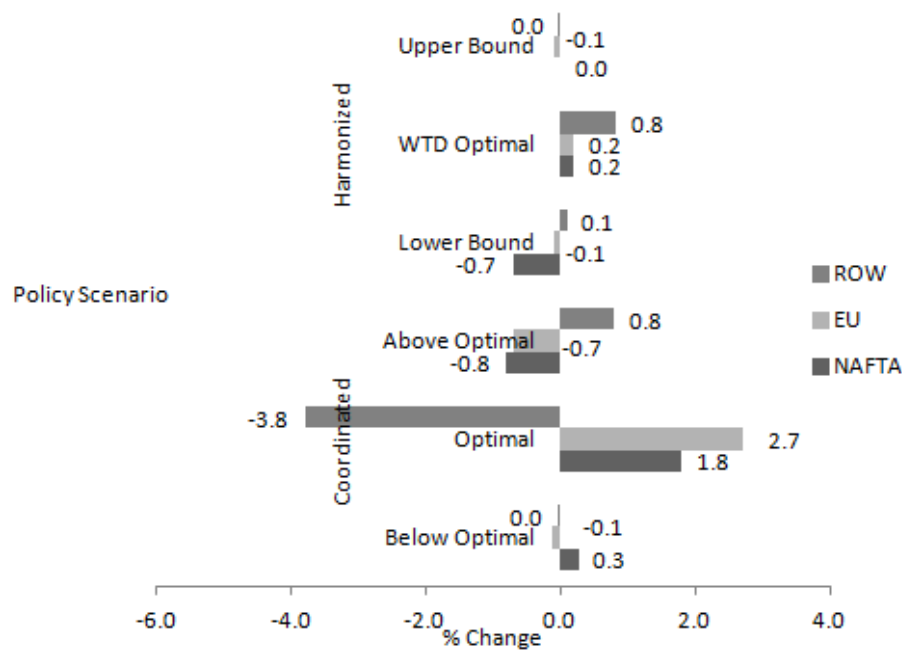
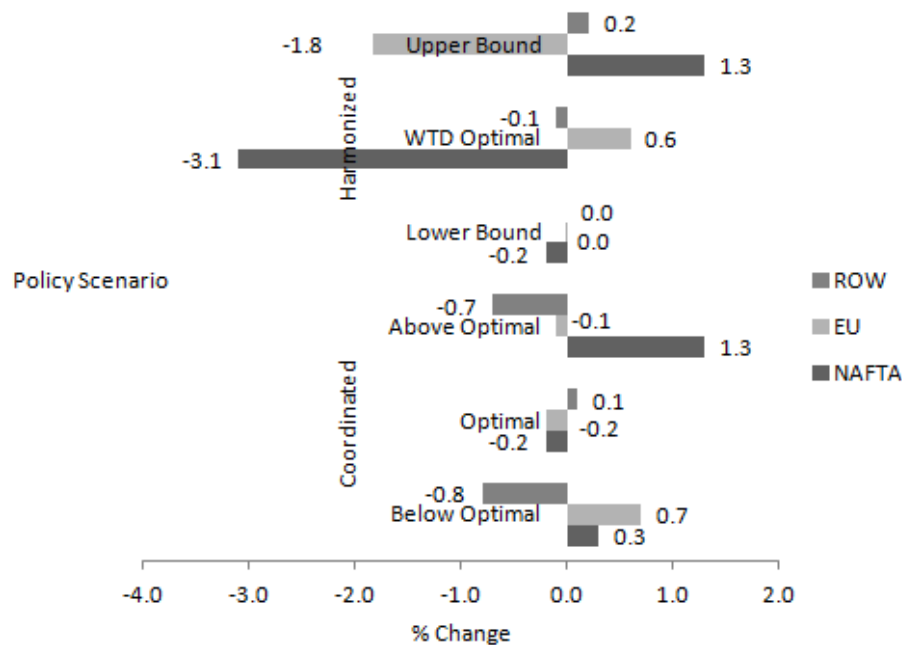


Figure 6.6: Welfare Effects under Flexible Wage FTA Closure - SY\_IC (% Change)



Figures 6.5 and 6.6 depict welfare effects under no free trade and free trade assumptions respectively. Both figures reveal that the pattern of welfare changes differs considerably compared to the fixed wage case. Under the flexible wage no free trade scenario, the only significant welfare effects are associated with the optimal environmental tax scheme. Here,

both NAFTA and the EU experience higher welfare. For the EU, the higher welfare derives from a combination of a 2.4 percent rise in aggregate output and a 8.8 percent fall in the level of pollution. In the case of NAFTA, pollution falls by only falls by 3.7 percent. In contrast, welfare falls in the ROW because of a 3.6 percent fall in output and a significant rise in pollution.

Free trade significantly reduces the welfare effects under the optimal scheme. While free trade has adverse effects on NAFTA and the EU, it improves welfare in the ROW. The welfare change is  $-0.7$  percent, compared to 3.8 percent in the absence of free trade. In contrast, free trade strengthens welfare responses under the above optimal tax shock. NAFTA's welfare is 1.5 higher than baseline due to solely to an 11 percent fall in pollution. In the case of the EU, welfare reduction from a 1.5 fall in aggregate output is partially offset by a 14.3 percent fall in pollution. Overall, despite the symmetry between the regions, free trade has mixed effects on the outcomes of coordinated environmental taxes in both NAFTA and the EU. Regulatory responses differ because the market structure and demand elasticities in the two regions are different.

The effects are more pronounced under the harmonized tax scheme. This is particularly true when harmonized taxes are above minimum. A weighted optimal tax implemented in the absence of free trade marginally raises welfare in the two regulated regions because NAFTA experiences gains from improved air quality and a small gain in output. Similarly, the small output gain explains the marginal welfare improvement. Free trade however exacerbates NAFTA's welfare losses. Welfare falls by 3.1 percent despite the weighted tax being significantly lower than the region's baseline tax. The lower welfare is the result of a 0.8 percent fall in output, a 7.7 percent rise in pollution and a market structure effects. Pollution rises by 6.6 percent under the upper bound scheme, nevertheless, it is not strong enough to offset the welfare gains. Unlike NAFTA, the EU's welfare rises by 0.6 percent in response to a weighted tax cum free trade policy, but falls by 1.8 under the upper bound tax scheme.

## 6.5 Conclusion

This chapter demonstrates how coordinated and harmonized approaches to joint regulatory policy affect symmetric regions. Moreover, it illustrates how free trade affects the outcomes of joint policy between the two regions. Overall, output effects on NAFTA are negligible. For the EU, output effects of joint policy with NAFTA are small but significantly higher than NAFTA. Importantly, the results suggest that the non-participating region, the ROW, is more sensitive to regulatory changes in the two participating regions than the EU and NAFTA. This is true for both coordinated and harmonized taxes in the presence of real wage rigidities. In case of the EU, free trade improves the output responses under the harmonized regulatory scheme. When wages are flexible, regulatory effects are only significant under the optimal tax scheme. In comparing the two regulatory approaches, the results suggest that, the coordinated scheme combined with free trade results in output changes of less than 1 percent in all three regions.

Despite NAFTA's negligible output responses, market structure effects are more pronounced. The latter in part explains the regions insignificant output effects, because changes in market structure cushion the effects of regulatory taxes. For both NAFTA and the EU, coal is the most policy responsive sector, but policy effects are stronger in the EU's coal sector. Unlike NAFTA, the EU's induced effects are limited to the three energy-producing sectors.

The preceding discussion also reveals that while NAFTA's output responses are minor, welfare effects are larger. This is particularly true when regulatory policy is combined with free trade. In case of the EU, free trade improves the outcomes of harmonized taxes when the real wage for the unskilled labour category is fixed. Other than, free trade has perverse effects on policy outcomes for both NAFTA and the EU.

In essence, the discussion in this chapter suggests that, free trade has mixed effects on both the outcomes of coordinated and harmonized taxes. Moreover, even when regions are almost identical in every way, joint policy can affect the regions differently. In the case of a

harmonized scheme, any change in regulatory choices can affect competitiveness because of induces changes in market structure. Finally, labour market characteristics mainly affect the regulatory responses of the EU. In the case of NAFTA, regulatory outcomes are the same regardless of the labour market assumption. The next chapter brings together analysis from chapters 4, 5 and 6 to ascertain how market structure and the relative size of trading partners affect the way free trade interacts with joint regulatory taxes.

## Appendix 6.A

Table 6.5: Pollution Changes under Fixed Wage No FTA Closure- SY\_IC (%)

|        | Coordinated  |              |                 | Harmonized  |              |             |
|--------|--------------|--------------|-----------------|-------------|--------------|-------------|
|        | $\tau_E = 0$ | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$ | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 26           | -0.1         | -9.7            | 15          | 3.3          | -0.2        |
| EU     | 20           | 1.3          | -14.9           | 3.3         | -1.9         | -3.9        |
| ROW    | 47           | 46.7         | 46.5            | 45.7        | 46.8         | 47.2        |

Table 6.6: Pollution Changes under Fixed Wage FTA Closure- SY\_IC (%)

|        | Coordinated E-Taxes |              |                 | Harmonized E-Taxes |              |             |
|--------|---------------------|--------------|-----------------|--------------------|--------------|-------------|
|        | $\tau_E = 0$        | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$        | $\tau_{WTD}$ | $\tau_{UB}$ |
| Canada | 26                  | 0            | -11.8           | 7.9                | 4            | 0           |
| EU     | 17                  | 0.3          | -17.1           | 3.6                | -2.5         | -5.8        |
| ROW    | 47                  | 46.8         | 47.2            | 46.8               | 46.6         | 46.8        |

Table 6.7: Pollution Changes under Flexible Wage No FTA Closure- SY\_IC (%)

|       | Coordinated E-Tax |              |                 | Harmonized E-Tax |              |             |
|-------|-------------------|--------------|-----------------|------------------|--------------|-------------|
|       | $\tau_E = 0$      | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$      | $\tau_{WTD}$ | $\tau_{UB}$ |
| NAFTA | 25.3              | -3.7         | -20.6           | 5.6              | 3.8          | 0           |
| EU    | 9.5               | -8.8         | 13.8            | -0.4             | -1.9         | -5.3        |
| ROW   | 46.8              | 46.7         | 46.8            | 46.8             | 47           | 47.2        |

Table 6.8: Pollution Changes under Flexible Wage FTA Closure- SY\_IC (%)

|       | Coordinated E-Tax |              |                 | Harmonized E-Tax |              |             |
|-------|-------------------|--------------|-----------------|------------------|--------------|-------------|
|       | $\tau_E = 0$      | $\tau_{opt}$ | $\tau_E + \$10$ | $\tau_{LB}$      | $\tau_{WTD}$ | $\tau_{UB}$ |
| NAFTA | 27                | 1.9          | -10.6           | 28.3             | 7.1          | 6.6         |
| EU    | 13.4              | -4.7         | -5.2            | -10.1            | -23.9        | -28         |
| ROW   | 46.9              | 46.4         | 46.8            | 46.9             | 46.2         | 47.2        |

# Chapter 7

## MARKET STRUCTURE AND THE NATURE OF TRADE TIES

### Implications for Collective Environmental Policy Outcomes

*“treaties should be seen as  
instruments of strategy.”*

Scott Barrett

#### 7.1 Introduction

Trade linkage theorists agree on two major issues. First, in an increasingly integrated world, lack of cooperation on environmental issues has international implications and can affect domestic policy decisions. Second, concessions (positive or negative) within a linked agreement have the potential to infuse stability required for sustainable international environmental policy cooperation. Different strands of this body of literature highlight the centrality of trade to the functioning of any economy, the role of trade concessions as implicit monetary transfers (Turunen-Red and Woodland, 2004) and the possibility of environmental policy paying for itself through free trade (Beghin et al., 2002) as unique features that justify linking environmental policy to trade.<sup>1</sup> However, important questions are yet to be answered.

This chapter demonstrates how market structure and the relative size of trading partners influence the outcomes of joint regulatory policy by bringing together findings from the previous three chapters. In particular, I draw comparisons between the effects of coordinated and harmonized environmental taxes under perfect and imperfect competition, and

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<sup>1</sup>Likewise, Burguet and Sempere (2003) contend that when regions are symmetric, there are welfare gains from combining environmental taxes with free trade.

asymmetric and symmetric trade ties.

Studies that consider how market structure influences of regulatory shocks offer conflicting insights. For instance, Willenbockel (2004) finds no link between trade liberalization and market structure. Similarly, analyzing the effects of market structure on the coal sector regulation, Li (2012) finds that the coal sector is not sensitive to market structure considerations. In contrast, Hertel and Roland-Holst (1991) note that a regulatory policy instrument can yield contrasting results under perfect and imperfect competition. Ronson (2006) explains that compared to perfect competition, prices exhibit higher variability under imperfect competition. For this reason, regulatory shocks have stronger effects when markets are imperfectly competitive. This view is supported by Bohringer et al. (2008) and Conrad (2002).

The distribution of the regulatory burden and competitiveness are important considerations in international environmental policy cooperation. Studies show that regulatory changes have economic consequence regardless of the relative size of trading partners. Horstmann and Markusen (1992) and Krugman (1992) note that when markets are imperfectly competitive, trade changes can occur even when the trading partners are identical in all aspects.

For competitiveness concerns, harmonization of regulatory instruments is considered attractive because by subjecting all countries to the same tax, harmonization is likely to circumvent strategic incentives. Essentially, harmonization of taxes preserves the competitive landscape of international markets. Literature of the benefits of harmonization is mixed. A number of studies suggest that harmonization is potentially welfare improving. For instance, Behrens et al.'s (2007) explain that harmonization encourages efficiency when taxes across countries differ. Further, when regions are asymmetric, harmonization can be welfare improving for both regions if asymmetries derive from the distribution of the global consumer base or pollution damages (Conrad, 2002). Gallegos (2005) finds that the smaller region always gains from harmonizing taxes on polluting intermediates with larger region. McAusland (2005) offers a contrasting view. She contends that harmonization between

asymmetric regions tends to be inefficient. Likewise, Behrens et al. (2007) posit that tax harmonization when asymmetric regions compete under perfect competition always makes the smaller region worse off. In the case of imperfect competition, studies seem to agree that harmonization is potentially welfare improving.

If instead two symmetric regions harmonize taxes under imperfect competition, harmonization can make at least one region better off (Keen et al., 2002) or can be mutually beneficial (Behrens et al., 2007).<sup>2</sup> In contrast, McAusland argues that environmental tax harmonization can have adverse effects on both global welfare and the environment. Overall, the literature suggests that welfare gains depend on a number of conditions: the distribution of the global consumer base or pollution damages (Duval and Hamilton, 2004), sufficiently strong asymmetries (Cheickbossian, 2010), constant prices (Vlassis, 2013), or weighted taxes based on initial rates (Keen et al., 2002). Nevertheless, almost all these conclusions derive from theoretical studies.

The objective of this chapter is to demonstrate the importance of market structure and relative size considerations in designing joint regulatory policy. Like Duval and Hamilton (2004), asymmetries are derived from the distribution of the consumer base. In this case, the size of the internal market. Following Keen et al. (2002), I use weighted harmonized taxes based on initial baseline optimal environmental taxes. Further, like Gallegos (2005), corrective taxes target intermediate input use. However, unlike Vlassis (2013), prices are endogenous. To explore the role of market structure, I consider Canada-EU trade under perfect and imperfect competition.<sup>3</sup> Further, I use the Canada-EU and NAFTA-EU trade under imperfect competition, to demonstrate how the relative size of cooperating partners affects regulatory policy outcomes. As in the previous chapters, I consider two sets of results: The effects of regulatory policy when the labour market is characterized by real wage rigidities, and effects of regulatory policy when the wages are flexible.

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<sup>2</sup>Both Keen et al (2002) and Behrens et al. (2007) consider capital tax harmonization rather than environmental tax harmonization. The literature is included here because of the limited number of studies discussing environmental tax harmonization

<sup>3</sup>Regulatory cooperation within the auspices of the Canada-EU Comprehensive Economic and Trade Agreement (CETA).

The results suggest that the effects of free trade on environmental policy outcomes depend on the regulatory approach, the underlying markets structure and the relative size of trading partners. In the absence of free trade, I find that when markets are imperfectly competitive and trading regions are asymmetric, coordinating environmental taxes in the presence of real wage unemployment exerts significant output losses on the EU. In contrast, when markets are perfectly competitive, losses for the region are higher under a harmonized environmental tax no free trade policy scheme. Nevertheless, free trade unambiguously improves regulatory outcomes for the EU if environmental taxes are coordinated. In the case of Canada, market structure effects are less obvious and the effects of free trade are mixed. It is possible for the region to lose from a regulatory scheme combining environmental taxes with free trade. If however, wages are flexible, regulatory effects for both regions are lower. With regard to the relative size of trading partners, the results suggest that regulatory costs are higher when regions are asymmetric than symmetric. Interestingly, the non-participating region, the ROW, is more sensitive to policy changes in NAFTA and the EU. Notwithstanding, I find that market structure effects are stronger under the assumption of symmetry. Moreover, unlike the asymmetric case, free trade can have perverse effects on both NAFTA's and the EU's regulatory outcomes. Overall, harmonized regulatory taxes have competitiveness implications regardless of the size of the tax.

The following sections explore these findings in detail. Section 7.2 discusses how output effects of regulatory policy are influenced by market structure and size asymmetries. In particular, I contrast output effects under perfect competition and imperfect competition. Then I draw comparisons between output effects when trading regions are asymmetric vis a vis symmetric. Section 7.3 considers trade effects. Specifically, how changes comparative and competitive advantage differ under the three cases. Section 7.4 compares welfare effects, while the last section, 7.5, concludes the chapter.

## 7.2 Output Effects

Simulation results suggest that effects of environmental tax coordination and harmonization are sensitive to market structure and the relative size of trading partners. In particular, when regions are asymmetric, the effects of coordinated taxes are consistent with Bohringer et al.(2008), Ronson (2006) and Conrad (2002) who posit that policy effects under imperfect competition tend to be magnified compared to perfect competition. Similarly, comparisons between perfect and imperfect competition lend support to Hertel and Roland-Holst's (1998) assertion that of a policy intervention under the two market structures can be disparate.

Output effects under perfect competition depend directly the relationship between input costs, commodity prices and the level substitution between inputs. In contrast, output changes when markets are imperfectly competitive also depend of the changes in market structure induced by the entry and exit of firms. The net results of induced effects depend on the two opposing forces: changes in competition and scale economies. For instance, a reduction in production costs from the removal of trade barriers raises output because entry increases competition and as a consequence reduces the degree to which firms can raise prices over marginal costs. Nonetheless, entry crowds out scale economies and reduces output. The net effect of the lower production costs on output depends of which of the two effects is stronger. The opposite is true for a rise in production costs. For this reason, economic consequences of regulatory policy can have disparate effects under imperfect competition. This is exemplified in Tables 7.1 through 7.4 , where output effects of coordinated and harmonized environmental taxes under perfect and imperfect competition differ in magnitude or direction.

### 7.2.1 Output, Market Structure and Coordinated Environmental Taxes

Tables 7.1 to 7.2 summarize output effects of the three cases: asymmetric regions competing in perfectly competitive markets (ASY\_PC), asymmetric regions in imperfectly competitive

markets (ASY\_IC) and finally, symmetric regions competing under imperfect competition (SY\_IC). Results are tabulated according to regions; REG1 represents Canada under the asymmetric cases and NAFTA under the symmetric case. REG2 represents the EU in all three cases.

Table 7.1: Output and Coordinated E-Taxes under Fixed Closure (% Change)

| Levy   |              |                 | NO FTA              |                     |                    | FTA    |        |       |
|--------|--------------|-----------------|---------------------|---------------------|--------------------|--------|--------|-------|
| Region | Initial      | New             | PC_ASY <sup>a</sup> | IC_ASY <sup>b</sup> | IC_SY <sup>c</sup> | PC_ASY | IC_ASY | IC_SY |
| REG 1  | $\tau_{opt}$ | $\tau_E = 0$    | -1.8                | -0.3                | 0.2                | -2.4   | 3.9    | 0.0   |
| REG 2  | $\tau_{opt}$ | $\tau_E = 0$    | -0.1                | -2.0                | -1.5               | 2.4    | 2.8    | -0.7  |
| ROW    | $\tau_{opt}$ | 0.0             | -0.4                | -1.3                | 0.9                | -0.6   | 0.9    | 1.0   |
| REG 1  | $\tau_{opt}$ | $\tau_{opt}$    | 0.0                 | -0.1                | 0.0                | 0.0    | 0.0    | -0.1  |
| REG 2  | $\tau_{opt}$ | $\tau_{opt}$    | 0.0                 | -0.2                | -0.1               | -0.2   | 1.0    | -0.1  |
| ROW    | $\tau_{opt}$ | 0.0             | 0.0                 | 0.0                 | 2.1                | -0.1   | 2.0    | 4.7   |
| REG 1  | $\tau_{opt}$ | $\tau_E + \$10$ | 3.0                 | 3.0                 | 0.0                | -1.5   | 5.0    | -0.5  |
| REG 2  | $\tau_{opt}$ | $\tau_E + \$10$ | -1.4                | -1.9                | -0.2               | 0.0    | 1.1    | -3.6  |
| ROW    | $\tau_{opt}$ | 0               | -0.2                | 0.1                 | -0.4               | -0.4   | 0.5    | -1.1  |

<sup>a</sup> Asymmetric regions- perfect competition, where REG 1 represents Canada and REG 2, the EU

<sup>b</sup> Asymmetric regions- imperfect competition, where REG 1 represents Canada and REG 2, the EU

<sup>c</sup> Symmetric regions- imperfect competition, where REG 1 represents NAFTA and REG 2, the EU

Assuming first that coordinated policies are applied independent of free trade, Table 7.1 shows that under the fixed wage closure, regulatory costs for the EU in terms of foregone output, are lower under perfect competition. For instance, above optimal taxes result in an output loss of 1.9 percent under imperfect competition compared to 0.6 percent under perfect competition. Similarly, Table 7.2 shows that when the labour constraint is removed, the same policy results in a 1.2 percent reduction in aggregate output under imperfect competition compared 0.1 percent under the alternative market structure. Results under both wage assumptions suggest that in the absence of free trade, the distortionary effect of market power outweighs efficiency gains from higher scale economies in key sectors like

manufacturing and services. Because international markets are generally characterized by imperfect competition, analysis that is limited to perfect competition can underestimate the cost of regulatory policy.

For the EU, comparing output effects under the two market structures not only highlights differences in policy effects, but also shows that regulatory responses under free trade are more favourable under imperfect than perfect competition. This is true under both labour market assumptions. Further, results suggest that efficiency gains from trade liberalization and induced markets structure effects can outweigh the effects of higher production costs associated with environmental taxes.

While results for Canada are more favourable, market structure effects are less predictable. For instance, when wages are rigid, output effects in the absence of free trade are negligible under both trade assumptions. Output effects are negligible because while both Canada and the EU maintain their baseline tax levels, the change in relative prices vis a vis the ROW are negligible. When taxes are above optimal, output is 3 percent higher than baseline under imperfect competition and 0.1 percent under perfect competition. This result is consistent with earlier observations by Ronson (2006) and others. According to Ronson, regulatory changes under imperfect competition are stronger than perfect competition because when markets are imperfectly competitive, regulatory shocks cause a larger variation in prices. Table 7.1 shows that the same pattern is observed under free trade. Nevertheless, changes under the above optimal free trade scheme are significantly larger.

Essentially, the effects of free trade effects for Canada are mixed. First, Table 7.1 shows that under perfect competition, free trade depletes positive output gains from optimal taxes. Further, when compared to imperfect competition, the below optimal tax scenario results in a 1.6 percent fall in output under perfect competition compared to the 3.9 percent. Under both below and above optimal tax scenarios, free trade has positive and significant effects on Canada's output when markets are perfectly competitive. Essentially, when real wages are rigid, free trade improves Canada's responses to coordinated environmental taxes if markets are imperfectly competitive. Assuming that higher production costs from the stringent

environmental tax exceed lower costs from trade liberalization, the 5 percent gain in output under imperfect competition can in part be explained by efficiency gains from an expansion in scale economies as inefficient firms exit the market. Results indicate substantial scale expansion in key sectors like manufacturing, services and metals, while firm level markups in manufacturing and metals rise only by 1 percent in both sectors.

Table 7.2: Output and Coordinated E-Taxes under Flexible Wage Closure (% Change)

| Region | Levy         |                 | NO FTA |        |       | FTA    |        |       |
|--------|--------------|-----------------|--------|--------|-------|--------|--------|-------|
|        | Initial      | New             | PC_ASY | IC_ASY | IC_SY | PC_ASY | IC_ASY | IC_SY |
| REG 1  | $\tau_{opt}$ | $\tau_E = 0$    | 0.1    | 0.6    | 0.0   | -3.5   | 1.2    | -0.6  |
| REG 2  | $\tau_{opt}$ | $\tau_E = 0$    | -0.8   | 0.6    | 0.1   | -0.5   | 2.0    | 1.4   |
| ROW    | $\tau_{opt}$ | 0.0             | 0.3    | -0.3   | 0.0   | 0.3    | -0.8   | -0.5  |
| REG 1  | $\tau_{opt}$ | $\tau_{opt}$    | -1.0   | -0.3   | 1.8   | -3.1   | -3.3   | 0.7   |
| REG 2  | $\tau_{opt}$ | $\tau_{opt}$    | 0.6    | -0.1   | 2.4   | 0.0    | 1.6    | 1.0   |
| ROW    | $\tau_{opt}$ | 0.0             | -0.2   | 0.0    | -3.6  | 0.1    | -0.5   | -1.7  |
| REG 1  | $\tau_{opt}$ | $\tau_E + \$10$ | 1.4    | 0.6    | 0.0   | -1.5   | -0.5   | -1.4  |
| REG 2  | $\tau_{opt}$ | $\tau_E + \$10$ | 0.0    | -1.2   | 0.0   | 0.0    | -0.1   | 2.0   |
| ROW    | $\tau_{opt}$ | 0.0             | 0.0    | 0.5    | 0.0   | 0.0    | 0.1    | -0.1  |

If instead the economy is at full employment, output effects for Canada are larger under perfect competition. At full employment, the full adjustment in wages allows for more substitution between inputs. For this reason, the net effects of regulatory changes under perfect competition derive from direct cost effects and substitution activities. The 1 percent reduction in output is in part due to direct effects of higher production costs and a fall in investment and employment in the skilled labour category in all sectors. The latter result seems to suggest that when wages are flexible, firms are likely to respond to higher production costs by reducing output rather than input substitution.

In contrast, the 1.4 percent higher than baseline output associated with above optimal taxes suggests that the effects of substituting intermediates for capital more than offsets the

direct effect of higher production costs. The relationship between output changes and market structure is less obvious under free trade. Output effects of optimal environmental taxes are stronger when commodity markets are imperfectly competitive than perfectly competitive. Table 7.2 shows that the opposite is true when regulatory taxes are above optimal. When markets are imperfectly competitive, Canada's output under the optimal tax scenario falls. This is because the crowding out of scale economies resulting from increased entry more than outweighs the direct benefits of lower production costs when trade taxes are zero. The output contraction under the above optimal tax is much smaller because scale efficiency losses more than offset the benefits of increased capital substitution.

Now, considering the relative size of trading partners, asymmetric regions are more sensitive to coordinating regulatory taxes in presence of real wage unemployment than symmetric regions. Table 7.1 shows that output effects of coordinated environmental taxes in the presence of real wage unemployment are negligible for both participating regions under the assumption of symmetry. Interestingly, the non-participating region, the ROW, is more responsive to regulatory changes in NAFTA and the EU. As would be expected, the ROW's output is 2.1 percent higher than the baseline when optimal taxes are maintained in NAFTA and the EU. The gain in output is magnified under free trade as indicated by the 4.7 percent rise in output. While higher output would be expected given the relative cost advantage of zero regulatory taxes, the ROW is more responsive because the bulk of its trade is with the two regulating regions. Accordingly, even small fluctuations in prices in the regulating regions are likely to cause significant changes in economic activity in the ROW. Moreover, while NAFTA and the EU's internal markets account for the bulk of economic activity, the ROW relies heavily on the NAFTA-EU market as a destination for its exports. Similarly, the size of the internal markets explains why output effects are stronger when regions are asymmetric. This result implies that in the presence of real wage unemployment, Canada would lessen regulatory costs by entering into joint policy with the EU would under the auspices of NAFTA. Essentially, because Canada has a significantly smaller internal market than the EU, entering into joint policy with the EU would exert losses on the region, especially if combined with free trade.

When wages are flexible, output effects for all three regions are negligible save for effects under the optimal tax no free trade scenario. In this case, both the EU and NAFTA gain 2.4 and 1.8 percent in aggregate output relative to the baseline. Here again, regulatory effects are stronger in the non participating region (ROW); output in the ROW falls by 3.6 percent. This is in part due to changes in terms of trade. If optimal taxes raise the price of exports relative to imports in the two regions, a rise in terms of trade implies that part of the regulatory burden is being transferred to foreign consumers via higher prices, hence to sizable contraction in output. Further, the likely reallocation of resources from scale efficient sectors reinforces the fall in output.<sup>4</sup> For the asymmetric regions, output gains in Canada and the EU derive mainly from increased capital substitution and the crowding in of scale economies as firms exit the sectors. The results also reveal that NAFTA's manufacturing, coal and petroleum sectors enjoy gains in economies. Likewise, all three sectors plus services and transport enjoy scale expansion in the EU. Notwithstanding, the gains and losses under free trade are insignificant in all three regions. Now, drawing comparison between asymmetric and symmetric region output responses reveals that overall, at full employment, output effects under both assumptions are negligible.

Given this result, compliance to the environmental provisions in the Canada-EU Comprehensive Economic and Trade Agreement (CETA) would be mutually beneficial for both Canada and the EU in the long run. Nevertheless, over the short to medium run, commitment environmental obligations in Chapter 20 of the CETA could have adverse effects on Canada. Adhering to environmental obligations in the long run suggests that there is scope for the broader application of regulatory taxes for both Canada and the EU because costs of joint regulation are significantly low.

## **7.2.2 Output, Market Structure and Harmonized Environmental Taxes**

Beginning with comparisons of output effects under perfect versus imperfect competition, Table 7.4 shows that harmonization in the presence of real wage rigidities exerts significant

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<sup>4</sup>Because the regulated region accounts for the bulk of global activity, changes in relative prices have a stronger effect on the ROW.

costs on the EU when markets are perfectly competitive. Costs are particularly high in the absence of free trade.<sup>5</sup> This result is an expected outcome of harmonizing with a region with higher initial baseline environmental taxes. Nevertheless, the contrasting results under perfect and imperfect competition suggest that in the absence of free trade, ignoring induced market effects can overstate the costs of regulatory policy. For instance, when market are perfectly competitive, the EU's output falls by 5.3 percent compared to 1 percent under imperfect competition. Essentially, the relative cost advantage of harmonizing with Canada in the absence of free trade is partially offset by changes in market structure. Particularly, the efficiency gains from the reallocation of scale economies resulting from the exit of smaller firms. According to Table 7.4, once the labour market constraint is removed, regulatory effects of harmonized environmental taxes are negligible under both market structures. The fact that environmental taxes are harmonized could explain why this result is in contrast to Bohringer et al.(2008), Ronson (2006) and Conrad (2002) who find regulatory costs to be higher under imperfect competition.

In the case of Canada, the link between market structure and regulatory outcomes under real wage rigidities is less apparent. For instance, under perfect competition, losses arise from minimum and weighted harmonized environmental taxes. In contrast, losses under imperfect competition occur when harmonized taxes are above minimum. The latter result corroborates Willenbockel (2004) who finds trade policy shocks to be invariant to market structure assumptions. Notwithstanding, the distinction is more apparent when the labour market constraint is removed. Harmonization under imperfect competition results in larger output changes compared to perfect competition. The relaxing of the labour market constraint removes the constraint on substitution possibilities available to firms. For this reason, the full adjustment in relative input price is likely to affect market conduct.

Contrast between output effects of the weighted optimal tax scheme under perfect and imperfect competition reveals that output falls by 0.5 percent under perfect competition

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<sup>5</sup>In contrast to coordinated environmental taxes, harmonization when markets are perfectly competitive result in significant losses to the region compared to imperfect competition. For instance, the EU's losses from minimum, weighted optimal and upper bound minimum taxes are 2, 4.3 and 5.1 percent respectively, compared to a 2.8 percent gain from a minimum tax scheme, and losses of 3 and 1 percent from weighted optimal and upper bound schemes under imperfect competition.

and 3.1 percent under the alternative market closure. This result is a clear demonstration of how market structure affects regulatory outcomes. First, when markets are perfectly competitive, relatively lower costs of intermediates induce substitution away from capital. The latter seems to dominate that direct effect of relatively lower production costs. In contrast, when markets are imperfectly competitive, relatively lower production costs also induce entry and the consequence crowding out of scale efficiencies. For this reason, the reduction in output is larger.

Table 7.3: Output and Harmonized E-Taxes under Fixed Closure (% Change)

| Region | Levy         |              | NO FTA              |                     |                    | FTA    |        |       |
|--------|--------------|--------------|---------------------|---------------------|--------------------|--------|--------|-------|
|        | Initial      | New          | PC_ASY <sup>a</sup> | IC_ASY <sup>b</sup> | IC_SY <sup>c</sup> | PC_ASY | IC_ASY | IC_SY |
| REG 1  | $\tau_{opt}$ | $\tau_{LB}$  | 0.7                 | 0.2                 | 0.1                | -1.1   | 0.6    | -0.1  |
| REG 2  | $\tau_{opt}$ | $\tau_{LB}$  | -3.0                | 2.8                 | -0.1               | 0.2    | 0.0    | 2.0   |
| ROW    | $\tau_{opt}$ | 0.0          | -2.2                | -1.0                | 0.1                | 0.3    | 0.5    | 0.9   |
| REG 1  | $\tau_{opt}$ | $\tau_{WTD}$ | -0.2                | -2.2                | 0.2                | -0.3   | -4.0   | 0.0   |
| REG 2  | $\tau_{opt}$ | $\tau_{WTD}$ | -4.3                | -3.0                | 0.1                | -0.4   | -0.8   | -0.5  |
| ROW    | $\tau_{opt}$ | 0.0          | 0.3                 | 0.3                 | -0.2               | 0.6    | 0.0    | 4.2   |
| REG 1  | $\tau_{opt}$ | $\tau_{UB}$  | 5.3                 | -5.6                | 0.0                | 0.5    | 0.1    | 0.0   |
| REG 2  | $\tau_{opt}$ | $\tau_{UB}$  | -5.1                | -1.0                | -0.1               | -2.2   | -0.4   | 0.9   |
| ROW    | $\tau_{opt}$ | 0.0          | 3.0                 | 0.8                 | 0.0                | 3.0    | 1.1    | -0.3  |

<sup>a</sup> Asymmetric regions- perfect competition, where REG 1 represents Canada and REG 2, the EU

<sup>b</sup> Asymmetric regions- imperfect competition, where REG 1 represents Canada and REG 2, the EU

<sup>c</sup> Symmetric regions- imperfect competition, where REG 1 represents NAFTA and REG 2, the EU

Now, considering the policy outcomes under free trade, the simulations reveal that for the EU, free trade invariably results in lower regulatory costs in terms of foregone output, regardless of the labour market assumptions. As mentioned in chapter 6, the net effect of harmonized taxes under free trade depends on the upward adjustment from relatively higher input costs and downward adjustment from the removal of border taxes. In the case of the EU, the two effects almost offset each other, for this reason, the induced effect from market

structure changes is weak.

Table 7.4: Output and Harmonized E-Taxes under Flexible Closure (% Change)

| Region | E-Tax        |                  | NO FTA |        |       | FTA    |        |       |
|--------|--------------|------------------|--------|--------|-------|--------|--------|-------|
|        | Initial      | New              | PC_ASY | IC_ASY | IC_SY | PC_ASY | IC_ASY | IC_SY |
| REG 1  | $\tau_{opt}$ | $\tau_{LB}$      | 1.5    | 0.6    | -0.1  | 0.6    | 1.1    | 0.0   |
| REG 2  | $\tau_{opt}$ | $\tau_{LB}$      | -0.8   | 0.0    | -0.1  | 0.1    | -0.1   | 0.2   |
| ROW    | $\tau_{opt}$ | 0.0              | 0.2    | 0.0    | 0.1   | 0.0    | 0.1    | -0.1  |
| REG 1  | $\tau_{opt}$ | $\tau_{WTD}$     | -0.5   | -3.1   | 0.2   | 1.0    | -3.2   | -0.8  |
| REG 2  | $\tau_{opt}$ | $\tau_{WTD} = 0$ | -0.3   | 0.8    | 0.1   | 0.0    | -2.6   | 1.1   |
| ROW    | $\tau_{opt}$ | 0.0              | 0.1    | -0.2   | -0.2  | 0.0    | 1.1    | 0.3   |
| REG 1  | $\tau_{opt}$ | $\tau_{UB}$      | -0.1   | -1.3   | 0.0   | 0.1    | -0.1   | 0.1   |
| REG 2  | $\tau_{opt}$ | $\tau_{UB}$      | 0.2    | -1.4   | -0.1  | -0.3   | 0.4    | -1.5  |
| ROW    | $\tau_{opt}$ | 0.0              | -0.1   | 0.6    | 0.0   | 0.1    | -0.1   | 1.0   |

In comparison, free trade yields mixed effects for Canada. In this case again, there is no basis to conclude that regulatory effects improve with free trade or that imperfect competition intensifies regulatory responses. Under the fixed wage scenario, free trade reduces losses from minimum harmonized environmental taxes, but depletes the gains from the upper bound tax. Further, comparisons between perfect and imperfect competition in Tables 7.3 and 7.4 reveal that the most significant output losses occur when taxes are weighted optimal and markets are imperfectly competitive. This result is true under both wage assumptions. Notwithstanding, like the EU, Canada's output losses are higher when wages are rigid and harmonized taxes are applied without a corresponding removal of border taxes. Importantly, the two regulatory approaches have different implications for the two regions under both market structures. Costs of environmental tax harmonization for Canada are higher when markets are imperfectly competitive, whereas the EU experiences significant losses when markets are perfectly competitive. Now, given that international markets are predominantly imperfectly competitive, Canada would benefit more from a decision to harmonize

corrective taxes under the Canada-EU CETA if the regulatory taxes were minimum.<sup>6</sup> This result is consistent with Gallegos (2005) who finds a minimum harmonized tax on polluting intermediates to be beneficial to the smaller region.

Looking at the effects of the relative region size on harmonized environmental tax outcomes, the results suggest that in the absence of free trade output changes for both NAFTA and the EU are minor. This is the outcomes under both labour market assumptions. For NAFTA, negligible output effects extend to the free trade scenario. Given the assumptions model and the level size of corrective taxes, results suggest that NAFTA's output is not sensitive to regulatory choices. This is consistent with Jaffe et al. (1995) who illustrate that the US's GDP is not sensitive to changes in environmental stringency because regulatory costs account for an insignificant percentage of GDP. This argument can be applied to NAFTA because the US accounts for 85 percent of the region's total output. Now a comparison between policy outcomes under the asymmetric and symmetric region assumption reveals that the EU's regulatory effects are stronger when it harmonizes with Canada. However, key observations are worth mentioning. First, in the absence of free trade, a minimum harmonized tax scheme is more beneficial to the EU when it harmonizes with Canada as opposed to NAFTA. The sheer size of the EU's internal market vis a vis Canada implies that scale efficiency gains from increased market concentration are likely to have a larger positive impact on the region. Second, when harmonized taxes are above minimum, a joint policy with a region of similar size, NAFTA, is more beneficial.

Under free trade, results reveal that the effects of regulatory policy on the EU are stronger when it cooperates with NAFTA. NAFTA's regulatory responses are minor. The only significant change is the 0.8 percent fall in output when harmonized environmental taxes are weighted optimal. For the EU, when real wages are rigid, the presence of free trade does results in more favourable output effects when regions are symmetric, Case in point, the EU's output from lower and upper bound environmental tax cum free trade schemes rises by 2 and 0.9 percent when regions are symmetric, compared to 0 and  $-0.4$  percent when regions are asymmetric. Likewise, output effects are larger when under the flexible wage closure.

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<sup>6</sup>Set to equal Canada's optimal baseline taxes

However, the EU's outcomes when under the upper bound cum free trade policy are better when it cooperates with Canada because under the assumption of symmetry, output falls by 1.5 percent. The striking different in output effects under asymmetric and symmetric trade ties is largely due to the structural differences in the competing sectors. The results seem to suggest that while the upper bound tax scheme crowds in scale economies, the corresponding rise in firm level in manufacturing and services increases the distortionary effect of market power. In contrast, market power effects under the asymmetric assumption are minor.

A number of important insights can be drawn from the preceding discussion. First, when regions are asymmetric market structure has different implications for the EU. However, the results are consistent with predictions about the magnification of regulatory responses under imperfect competition. More importantly, collective environmental taxes combined with free trade invariably improve the EU's regulatory outcomes. In addition, the region's regulatory costs are lower when it combines regulatory policy with a region of similar size. These observations therefore suggest that the EU can lessen its regulatory burden by collective environmental taxes with free trade when it trades with Canada. Alternatively, the EU can cooperate with a region of similar size like, NAFTA. In contrast, free trade does not always benefit Canada. It is possible for the region to lose by combining free trade with regulatory action. If the degree of integration between Canada and the US is significant, then it would be beneficial for Canada to enter a joint policy with the EU under the auspices of NAFTA. Finally, because regulatory effects on NAFTA's output are negligible, there is scope for broader application of environmental taxes in the region.

### **7.3 Trade Effects, Market Structure and Size Asymmetries**

At the aggregate level, effects of environmental taxes on the volume of trade are negligible. In fact, results support earlier findings by Tobey (1990), van Beers and van den Berg (1997) and Harris et al. (2002) that trade volumes are not sensitive to regulatory stringency. Under standard neoclassical assumptions, theory dictates that relative cost changes from pollution

taxes affect comparative advantage and the direction of trade. Departing from standard the trade literature, extended trade theories (new trade theories) highlight the presence of two-way trade in similar goods and economies of scale. The existence of intra-industry trade makes it difficult to ascertain the direction of trade. According to Markusen (1992), the analysis of trade is rather complex and distribution of gains can be indeterminate, For this reason, to understand changes comparative advantage, relative gains area analyzed within the context of the changing scale economies and composition of trade. In this thesis, costs measured in terms of equilibrium prices are used to discuss changes in comparative advantage.

### **7.3.1 Coordinated Environmental Taxes, Trade and Market Structure**

Results suggest that while aggregate trade flows are generally not responsive to regulatory choices, flows between symmetric trading regions are slightly more responsive. This might seem counter intuitive, however, Markusen (1992) and Krugman (1992) note that in the presence of imperfect competition, trade changes can occur even if trading partners are identical in all aspects. When regions are asymmetric, Canada's sectors are more responsive to regulatory choices than the EU. Likewise, when regions are symmetric NAFTA's sector are more sensitive to regulatory choices than the EU. Further, Compared to Canada, sectoral changes in NAFTA are more visible. This essentially implies that the regulatory pulse will be felt by NAFTA's sectors even if on aggregate, output does not change. This observation lends support to Tobey (1990), and van Beers and van den Berg (1997).

Theoretically, when markets are perfectly competitive, sectors that use the regulated intermediate more intensively are expected to shrink because of corrective taxes on polluting intermediates, while sectors that are capital and labour intensive gain. The latter result however depends of the complementarity or substitutability between polluting intermediates and primary inputs.

Considering the effects of market structure on regulatory outcomes, results suggest that when the real wage of the unskilled labour category is fixed, relative price changes

are stronger under perfect competitive compared to imperfect competition. In addition, Canadian sectors are more sensitive to regulatory choices when markets are perfectly competitive. This result is in direct contrast to Bohringer et al. (2008), who find structural changes under imperfect competition are more significant under imperfect competition. The authors however assume flexible wages and a single carbon tax as opposed to input specific taxes and the real wage rigidities assumed in this section.

When markets are perfectly competitive, most shifts in comparative advantage occur in the agriculture, chemicals, pulp and paper, manufacturing and petroleum sectors. For Canada, the most significant shift occurs in the petroleum sector, where comparative advantage falls in response to an above an optimal environmental tax. In contrast, the EU loses comparative advantage in gas production as prices rise by 11 percent. When markets are imperfectly competitive, the implementation of optimal corrective taxes in Canada results in losses in comparative advantage in both regulated and non-regulated sectors. The most significant losses occur in the manufacturing sector. However, these shifts are not accompanied by changes in competitive advantage. For instance, under the above optimal environmental tax scheme, the results suggest sizable gains in comparative advantage in petroleum, gas and transport sectors. Correspondingly, the 22, 14 and 1 percent increase in firm level markups in the three sectors signal gains in competitive advantage.

Similarly, the move from zero to optimal environmental taxes in the EU reduces the manufacturing sectors comparative advantage. Nevertheless, unlike Canada, only the non-regulated sectors of manufacturing, transport and services experience losses in comparative advantage. According to the simulation results, comparative advantage in manufacturing shifts to the non-participating region. The latter result reflects the observable shift in manufacturing to Asian regions. Compared to shifts under perfect competition, the EU's gas sector experiences a gain in comparative advantage when optimal taxes are applied.<sup>7</sup> Higher production costs associated with above optimal taxes crowd out scale economies in manufacturing, transport and services. As a result comparative advantage shifts to the ROW. Nevertheless, because markups do not change, all three sectors retain their competitiveness.

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<sup>7</sup>Comparative advantage shifts from the ROW to the EU.

While output costs of policy between symmetric regions are minor, the results suggest that market structure changes are more pronounced. This is particularly true for NAFTA. Case in point, the move from zero to optimal environmental taxes in the absence of free trade depletes NAFTA's comparative advantage in both regulated and non-regulated sectors. Expressly, the manufacturing, gas, metals, pulp, and paper lose comparative advantage as higher production costs reduce scale economies. In contrast, the petroleum sector gains comparative and competitive advantage. When trade is liberalized, entry of new firm's crowds out scale economies in the petroleum sector as a result the sector's comparative advantage falls in response to a policy combining an above optimal environmental tax with free trade. The loss in comparative advantage extends to gas, manufacturing and transport sectors. However, only firms in petroleum and gas sectors experience losses in competitive advantage as markups fall by 7 and 3 percent respectively.

In the absence of free trade, comparative advantage in gas production shifts from NAFTA to the EU when environmental taxes are zero. The reverse is true for petroleum. If instead, environmental taxes are above optimal, results suggest a shift reversal of comparative advantage in the production of gas as higher prices induce firms to exist and a rise in scale economies. In addition, the non-regulated sectors, manufacturing and transport gain comparative advantage as higher costs of intermediates cause inefficient firms to exit the markets. In contrast, the petroleum sector loses comparative advantage to NAFTA and becomes less competitive as firm level markups fall by 17 percent. The petroleum sector's comparative advantage under free trade also falls. However, unlike the no free trade scenario, both NAFTA's and the EU's comparative advantage shifts to the ROW. The pulp and paper, manufacturing and services sectors experiences a contraction in scale economies. However, their competitive advantage does not change because the fall in unit costs results in a corresponding fall in prices. In other words, markups remain constant despite the loss in comparative advantage.

Now the contrast between trade effects under asymmetric and symmetric regions yields the following insights. First, assuming no free trade, results suggest that the move from zero environmental taxes to optimal results in comparative advantage gains in the gas, trans-

port for Canada. The EU gains advantage in the production of petroleum but experiences losses in manufacturing transport and services. When paired with a region of similar size the EU still loses comparative advantage in manufacturing. However, like the asymmetric case, comparative advantage in the production of petroleum falls. Correspondingly, when regions are symmetric, the imposition of optimal corrective taxes causes firms in petroleum and manufacturing sectors to become less competitive. This difference is in part due to differences in relative elasticities.

If instead, environmental taxes are combined with the removal of border taxes, scale changes in the EU are stronger when it cooperates with NAFTA than Canada. The changes in the structure of trade also differ slightly. For instance, when it cooperates with Canada, the move from zero to optimal environmental taxes shifts comparative advantage in favour of petroleum production. The opposite is true if it cooperates with NAFTA. For other sectors like transportation and gas, losses in comparative advantage occur regardless of the size of its cooperating partner. However, when a more stringent policy stance is taken, more sectors experience gains in comparative advantage under the assumption of symmetric regions than asymmetric. In particular, gas, pulp and paper, manufacturing, transportation and services all experience positive scale effects compared to only gas and manufacturing under the asymmetric case. Contrasting structural changes between the Canada and NAFTA, results suggest that the shift in comparative advantage services and petroleum sectors follows a similar pattern; they both gain when taxes are optimal, but lose when the above optimal scheme is applied. This suggests that impact of free trade of industrial elasticities in the two sectors is the same. Notwithstanding, while the above optimal cum free trade policy generates comparative advantages for Canada's manufacturing sector, NAFTA's manufacturing sector loses.

Once the labour constraint is removed, structural effects of coordinated taxes on trade are not as significant. Beginning with output effects in the absence of free trade, comparisons of structural effects under perfect and imperfect competition suggest that sector specific trade effects of moving from zero to optimal taxes are limited to a few sectors. In Canada, structural shifts occur mainly in the petroleum and capital goods sectors. When markets

are perfectly competitive, the region's petroleum sector loses comparative advantage, while the capital sector gains. However, when markets are imperfectly competitive, the changes in relative price of petroleum are lower and therefore capital gains. In addition, shifts in comparative advantage are stronger when markets are imperfectly competitive. A result consistent with Bohringer et al. (2008) and Ronson (2006) who find the presence of scale effects magnify trade effects.

If instead trade is liberalized, the movement from zero to optimal taxes under perfect competition causes a direct upward cost adjustment in both Canada and the EU rise. Because the rise in costs results in different relative costs, Canada loses cost advantages in the production of petroleum and manufactured goods. At the same time, the region gains minor cost advantages in the production of gas, chemicals and capital goods. In contrast, when markets are imperfectly competitive, the regulatory pulse is stronger and affects all of Canada's sectors. To illustrate, optimal environmental taxes cause equilibrium prices in agriculture, petroleum, gas and transport to rise by 4, 57, 4 and 2 percent respectively. In agriculture, prices rise despite a 2.6percent fall in markups because entry crowds out scale economies. The sectors lose both comparative and competitive advantage. Scale economies in petroleum rise therefore the sectors gain in comparative advantage derives mainly from scale efficiency effects. Unlike Canada, only the petroleum experience significant changes in relative costs. Similar changes occur under symmetric trade ties.

### **7.3.2 Harmonized Environmental Taxes, Trade Effects and Market Structure**

This sub-section considers how the regulatory responses to harmonized environmental taxes on are affected by market structure and relative size asymmetries. The main argument for the harmonization regulatory taxes is to preserve the competitive landscape of international markets. Simulation results indicate that when regions are asymmetric, this conclusion holds only for the non-energy sectors. When regions are symmetric, changes in harmonized policy affect market structure. While policy harmonization unifies regulatory taxes across regions, the effect of the regulatory policy on the competitive landscape depends on among

other factors, the design of the harmonized scheme and the degree of asymmetries across regions.

In comparing structural effects in the presence of real wage rigidities, the results reveal that when regions are asymmetric, relative cost changes are larger under imperfect competition compared to perfect competition. For instance, when border taxes are zero, the minimum harmonized tax scheme raises Canada's relative price of petroleum rises by 7 percent under perfect competition compared to 36 percent under imperfect competition. Similarly, relative price of coal rise by 2 percent under perfect competition compared to 20 percent under the alternative market structure. However, in the imperfectly competitive case both sectors gain comparative advantage from a minimum harmonized environmental tax cum scale economies expand. Scale economies in Canada's petroleum sector expand because compared to the EU, prices do not fall quickly owing the relatively smaller internal market. This effect outweighs the region's cost advantages associated with the minimum harmonized scheme. Consequently, higher costs relative to the EU and the ROW cause inefficient firms to exit the market, therefore, scale economies rise. However, despite scale efficiency gains, the exit of firms raises the ability of firms to raise prices above marginal costs. In fact, firm level markups rise by 35 percent in the petroleum sector and 1 percent in manufacturing. For this reason, both sectors gain comparative advantage due to scale efficiencies and competitive advantage because firm level markups are higher.

Considering the relative size of trading partners, harmonized taxes affect mainly petroleum, coal and gas sectors under both asymmetric and symmetric trade ties assumption. When regions are asymmetric, higher relative costs from harmonizing with a high tax region shifts EU's comparative advantage in the production of petroleum to Canada, when the minimum harmonized scheme is applied without a corresponding reduction in border taxes. Likewise, when regions are symmetric, the minimum harmonized environmental tax scheme raises NAFTA's comparative and competitive advantages in petroleum and gas. The opposite is for the EU. However, unlike the asymmetric case, results suggest that structural changes can potentially shift in comparative and competitive advantages from both the EU and NAFTA to in the unregulated region (ROW). This is true for the manufacturing, petroleum

and transport sectors.

The structural profile is significantly different when wages are flexible. A comparison of trade effects under perfect and imperfect competition reveals sectors are more responsive to regulatory choices when markets are imperfectly competitive. In addition, Canada's sectors are more responsive to regulatory choices than the EU. A key distinctive feature of harmonized environmental taxes under perfect competition is the sensitivity of Canada's agricultural sector to regulatory taxes. In fact, results show that Canada's comparative advantage in agriculture falls under all three harmonized tax schemes. For instance, competitiveness in agriculture falls as markups fall by 1.8 percent. The results from chapter 5 illustrated in Figure 5.5 suggest that regulatory shocks almost of Canada's sectors when markets are imperfectly competitive. Further, the sectors more likely to become less competitive is the coal sector. Overall, competitiveness losses are more significant in the absence of free trade. Like Canada, sectoral effects are more pronounced under imperfect competition. Nevertheless, only the three energy sectors are responsive to policy changes in the EU.

Considering the relative size of trading partners, structural effects of harmonized environmental taxes are more significant when regions are symmetric. The regulatory pulse affects the competitiveness of all sectors in all three regions. In contrast, the regulatory shocks under the asymmetric assumption have a stronger effect on Canada's competitiveness and affect mainly the EU's three energy sectors. It follows that market structure effects are the likely explanation for the minor regulatory costs when regions are symmetric. Further, the results suggest that markup effects on the three energy sectors are more pronounced under the assumption of symmetry.

All considered, several insights emerge from harmonized environmental taxes. In terms of market structure, sectoral effects are magnified under imperfect competition. Considering region asymmetries, results suggest the regulatory policy has a broader impact of sectors when regions are symmetric. The most policy sensitive sectors are petroleum, coal and gas. However, manufacturing also experiences notable changes in comparative advantage.

Further, policy when wages are flexible affects more sectors compared to policy when real wages are rigid. Furthermore, the presence of free trade reverses Canada's gains in comparative advantage. Moreover, structural effects a regulatory instrument can have opposite effects under perfect and imperfect competition. A result consistent with Roland-Holst and Hertel's (1998) observation that costs of a particular intervention can have disparate effects under the two regulatory approaches.

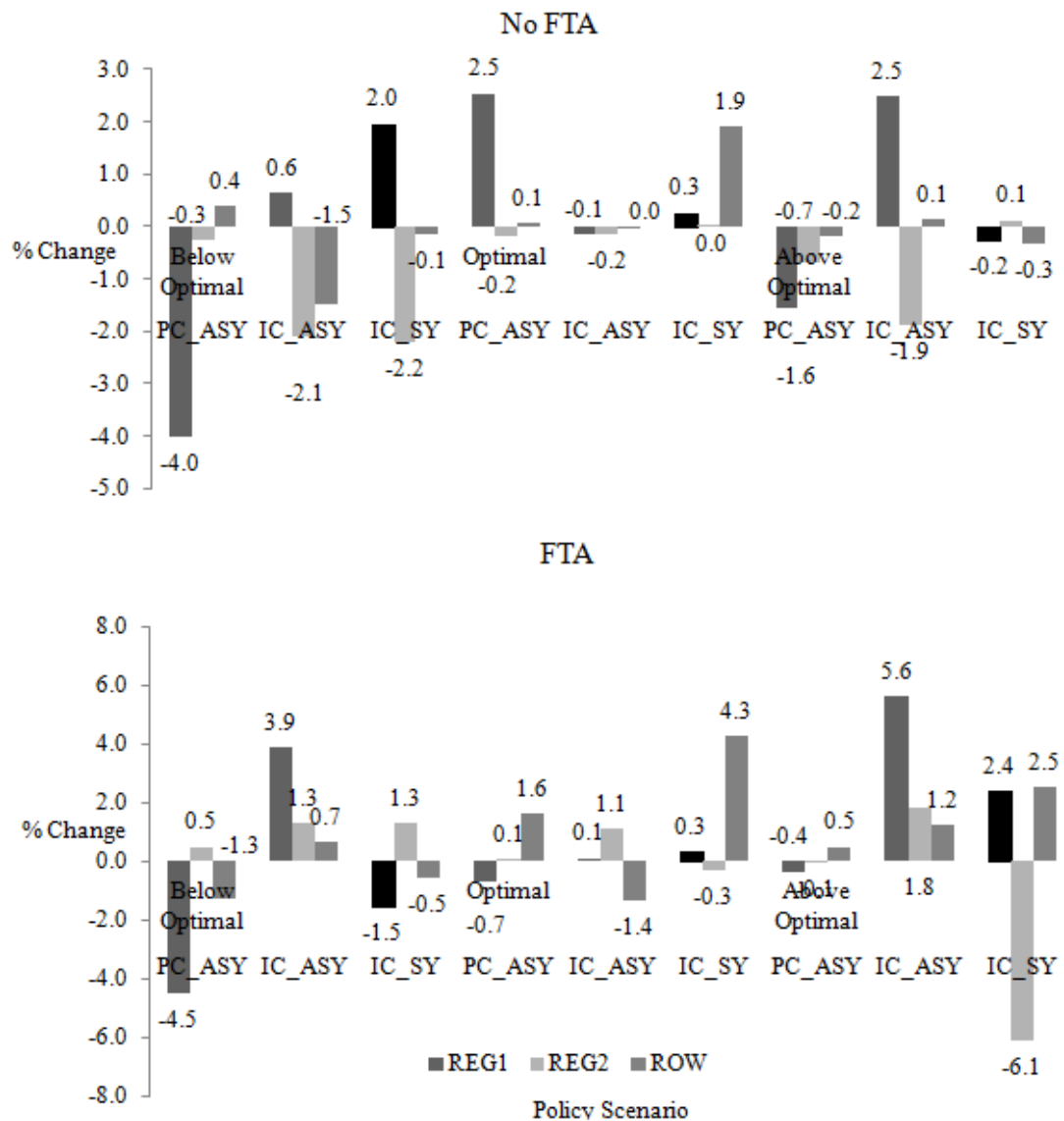
## **7.4 Welfare, Market Structure and Size Asymmetries**

In this section, I contrast welfare effects under perfect competition to imperfect competition, and asymmetric to symmetric trade ties. The net welfare changes under imperfect competition are more complex to analyze because in addition to direct output, trade and pollution changes, efficiency gains/losses of scale economies and increased market power also affect welfare. To add to the complexity, the last two effects act in opposite directions.

### **7.4.1 Welfare Effects when Environmental Taxes are Coordinated**

To ascertain the how market structure influences welfare outcomes of collective taxes, I draw comparisons between welfare effects when asymmetric regions compete in perfectly competitive markets (ASY\_PC) and asymmetric regions competing under imperfect competition (ASY\_IC). Further, to analyze how the relative size of trading partners affects welfare outcomes, I compare welfare effects of asymmetric regions competing in imperfectly competitive markets (ASY\_IC) and symmetric regions under the same market structure (SY\_IC). Figures 7.1 through 7.4 summarize welfare effects of the three market structures. To examine whether free trade improves regulatory outcomes, I compare each case under the no free trade and free trade assumptions.

Figure 7.1: Welfare Effects of Coordinated Taxes under the Fixed Wage Closure



Assuming that coordinated taxes are implemented without the corresponding removal of border taxes, Table 7.1 reveals that when the EU decides to implement a zero environmental tax (below optimal) policy, it incurs welfare costs of 0.3 percent under perfect competition and 2.6 percent when markets are perfectly competitive. In both cases the contraction in welfare derives from increased pollution and a fall in aggregate output. However, the loss under imperfect competition is significantly larger because the fall in production costs associated with the move from the baseline optimal to zero taxes attracts entry. The increase competition in key sectors crowds out scale economies and assuming that the ef-

fect of the loss in scale economies exceeds the positive effect of increased competition, the initial fall in output is reinforced by scale efficiency losses. More importantly, the region experiences losses from positive environmental taxes. A close look at the above optimal tax reveals that the EU's losses are significantly higher under imperfect competition. If instead, border taxes removed, Figure 7.2 illustrates that gains from free trade more than offset the losses in all tax scenarios involving asymmetric trade ties.

For Canada, Figure 7.1 shows that for positive environmental taxes, the region's welfare varies according to market structure. It is however, difficult to establish a clear pattern. When markets are perfectly competitive, optimal environmental taxes applied independent of free trade result in a welfare loss of 4 percent. The same policy under imperfect competition raises welfare by 1.9 percent. Likewise, the above optimal tax applied under perfect competition results in a 1.6 percent loss in welfare and a gain of 2.5 percent when markets are imperfectly competitive. The fall in welfare under perfect competition derives from the direct effects of higher costs on output that outweigh the benefits of lower pollution (−6.9 percent). However, when induced market structure effects are considered the region's welfare is 2.5 percent higher than the baseline level, a considerable shift from the perfectly competitive case. Here, the higher production costs result cause inefficient firms to exit the market and consequently a rise in scale economies in petroleum coal and gas.

For positive environmental taxes, Canada's welfare profile under free trade differs considerably compared to the no FTA scenario. For instance, when markets are perfectly competitive, optimal and above optimal tax schemes result in minor changes in welfare compared to the no FTA case. However, when market structure is considered, coordinated taxes have opposite but negligible under both perfect and imperfect competition. It is worth noting that under perfect competition, free trade reverses welfare gains. The difference under imperfect competition suggests that induced effects from changes in markups and scale economies can offset Canada's losses from combining free trade with regulatory policy. Unlike the perfectly competitive case, Canada's welfare response to the removal of environmental taxes is 3.9 percent higher than baseline. Similarly, welfare effects from an above optimal tax are positive and significant at 5.6 percent. The welfare gain under the above optimal

tax scenario results from the 5.2 percent fall in pollution is reinforced by a 5 percent gain in output. As in the previous case, scale efficiency effects from increased market concentration result in higher output.

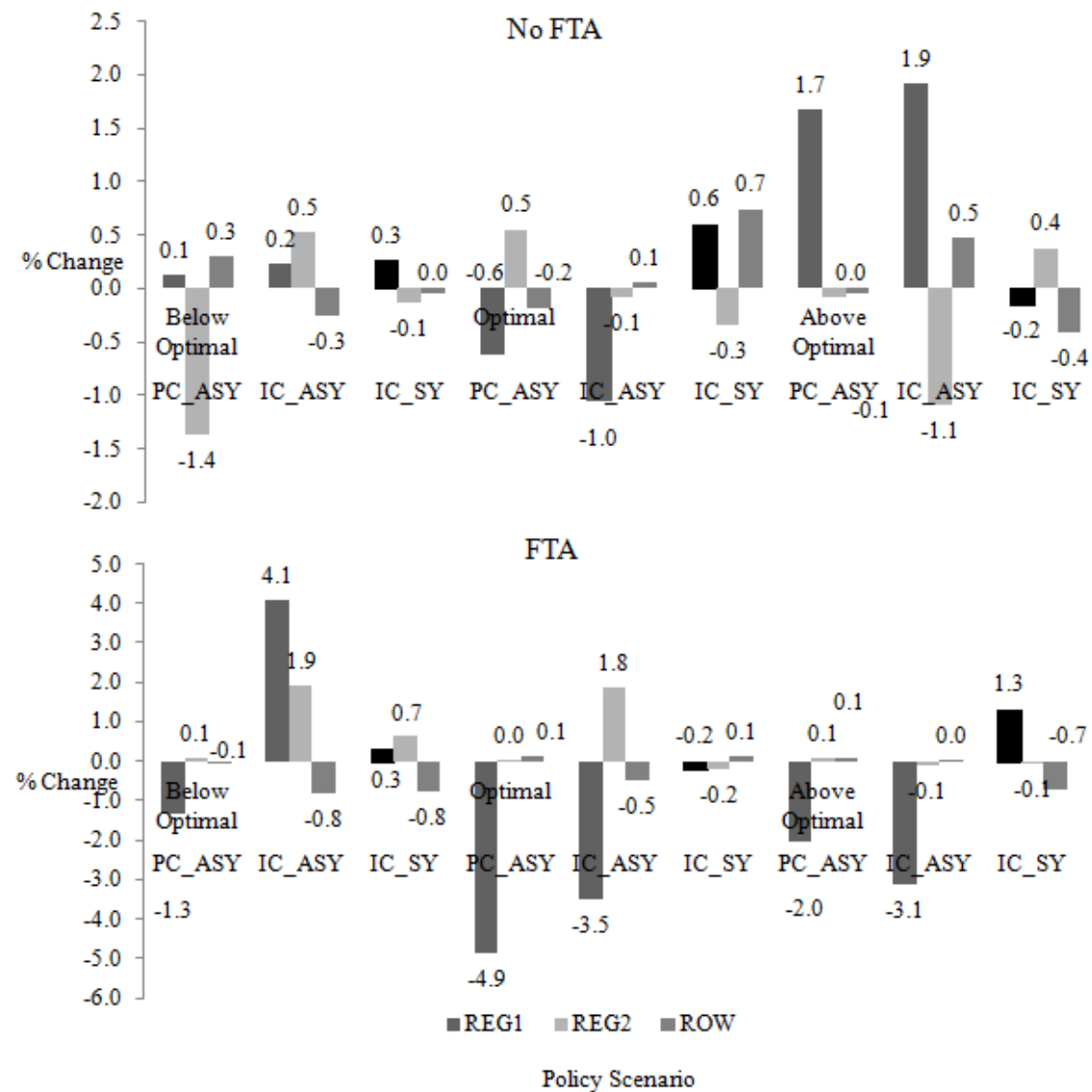
The case of symmetric regions in the presence of real wage rigidities shows that welfare costs of coordinated taxes for the EU lower in the absence of free trade. Likewise, NAFTA experiences trivial welfare changes for positive coordinated taxes applied in the absence of free trade. In the absence of free trade, the region's welfare is higher by 2 percent when both regions choose not to regulate their polluting inputs. However, when border taxes are zero, NAFTA experiences a loss of 1.5 percent. It however, experiences a 2.5 percent rise in welfare when above optimal taxes are combined with free trade. The gain is mainly due to a 14 percent fall in pollution. Further NAFTA's welfare is 3.5 percent higher when the optimal taxes are combined with free trade.

In contrast, the EU gains under all policy scenarios. Comparing the region's welfare outcomes when it trades with Canada versus NAFTA, results reveal that a policy that combines free trade with a more restrict regulatory policy raises welfare by 1.8 percent, if it cooperates with Canada, and 1.7 percent when it cooperates with NAFTA. Free trade therefore, invariably increases the EU's welfare when coordinated taxes are applied in the presence of real wage rigidities regardless of the size of its trading/cooperating partner. Despite the 3.6 percent fall in output, the region's welfare rises because pollution falls by 17 percent.

Relaxing the wage constraint, Figure 7.2 illustrates that welfare changes in range from  $-1.4$  to  $1.9$  percent in the absence of free trade, and  $-4.9$  to  $4.1$  percent under free trade. If we first consider the implications of market structure on regulatory outcomes, results in Figure 7.2 suggest that welfare losses are more pronounced under imperfect competition. A result that confirms earlier conclusions by Ronson (2006). Beginning with the no FTA scenario illustrated in the upper panel of Figure 7.2, the results suggest that for positive coordinated environmental taxes, Canada's welfare falls under both perfect and imperfect competition. Nevertheless, the region's welfare responses are stronger when commodity

markets are imperfectly competitive. For instance, the loss associated with an optimal coordinated tax is 0.6 percent under perfect competition and 1 when markets are imperfectly competitive. Similarly, the welfare gain under the above optimal tax scheme is 1.7 percent under perfect competition and 1.9 percent under the alternative market closure.

Figure 7.2: Welfare Effects of Coordinated Taxes under the Flexible Wage Closure



Comparatively, under free trade, Canada experiences sizable welfare costs as illustrated by in the bottom panel of Figure 7.2. Moreover, costs are much higher when markets are imperfectly competitive as evidenced by the -3.5 and -3.1 percent change under imperfect competition compared the -0.4 and -2 percent change under perfect competition. This

result highlights the importance of market effects in determining realistic regulatory costs. Here, while the manufacturing sector gains scale economies, firms in the services sector lose, and because the latter is a much larger contributor to aggregate output, welfare falls. On the contrary, when taxes are above optimal, free trade has minor effects under perfect competition, but reinforces gains under imperfect competition as shown by the 5.6 rise welfare. Overall, free trade has mixed effects on Canada.

For positive values of environmental taxes, the EU's welfare is lower than the baseline regardless of market structure. The most significant loss in welfare is associated with the above optimal tax when markets are imperfectly competitive. The rest of the policy scenarios result in minor welfare changes under both perfect and imperfect competition. The welfare loss associated with the above optimal tax is the net effect of a 1.9 percent fall in aggregate output and a 3.2 percent fall in pollution. The latter partially offsets the welfare loss from lower output. The loss is significantly higher under imperfect competition because induced changes in market structure increase the distortionary effect of market power. Results in the lower panel of Figure 7.1 reveal that free trade more than offsets welfare losses under imperfect competition. Welfare is 1.1 and 1.8 percent higher under optimal and above optimal tax schemes respectively. These results seem to suggest that while free trade reduces both market power and scale efficiencies, efficiency gains from reduced market power more than offset efficiency losses from the reallocation of scale economies. Drawing comparisons with results under the fixed wage closure, this outcome implies that when the economy is at full employment, coordinated environmental taxes can result in positive gains for the EU if combined with free trade. These results also reveal that, when wages are flexible, market structure is not an important determinant of how free trade affects regulatory outcomes, the EU.

Now considering the implications of the relative size of trading partners for coordinated environmental taxes, results are mixed. In the presence of real wage rigidities, optimal taxes in the absence of free trade have minor effects on both regions under both asymmetric and symmetry trade. Nevertheless, when regions are symmetric, the ROW is more responsive to the optimal environmental tax scheme in NAFTA and the EU. Welfare for the ROW is 1.9

percent higher than baseline. The logic here is straightforward; the direct effects of lower production costs outweigh induced market structure effects. The welfare gains from higher output are partially offset by the high levels of pollution in the ROW. Nevertheless, welfare effects of the more restrictive tax are minor for all three regions under the assumption of symmetric but sizeable for Canada and the EU when regions are asymmetric.

Under free trade, both asymmetric and symmetric regions are more responsive to regulatory changes. First, under the optimal tax scheme, the welfare gains for the ROW rises to 4.3 from 1.9 percent in the absence of free trade. Importantly, when wages are flexible, the EU's welfare is higher when regions are asymmetric. Further, the EU enjoys an 1.8 percent rise in welfare when it cooperates with Canada but experiences a 6.1 percent fall in welfare when it cooperates with NAFTA. This result suggests that when regions are asymmetric, free trade confers positive gains on the EU, while it results in losses when the EU is paired with a region of similar size. The advantage of a relatively large internal market explains the disparate results under the two relative size assumptions. It is worth mentioning that while the region experiences a 17 percent fall in pollution from a restrictive tax scheme under the free trade assumption. Nonetheless, these gains in environmental quality do not translate into welfare gains. Duval and Hamilton (2002) argue that efficiency gains from higher scale economies can still result in lower welfare if allocated to less efficient sectors. For NAFTA, efficiency gains combined with lower pollution result in a 2.4 percent rise in welfare.

When wages are flexible, Figure 7.2 shows that welfare effects when trading regions are symmetric are negligible regardless of the trade assumption. The largest change in welfare accrues to NAFTA when the above optimal environmental taxes are combined with free trade. NAFTA's welfare is 1.3 percent higher than baseline due largely to the reduction in pollution and employment effects. Nevertheless, welfare effects are still stronger when regions are asymmetric. In the absence of free trade, Canada's welfare falls by 1 percent while the change in the EU is insignificant. Free trade worsens Canada's losses, but improves the EU's welfare outcomes. In contrast, free trade reverses Canada's welfare gains under the above optimal scheme but almost offsets the EU's losses. As in the previous case, the EU's outcomes under free trade are better when it cooperates with Canada because of the

size of its internal market vis a vis Canada.

#### **7.4.2 Welfare Effects when Environmental Taxes are Harmonized**

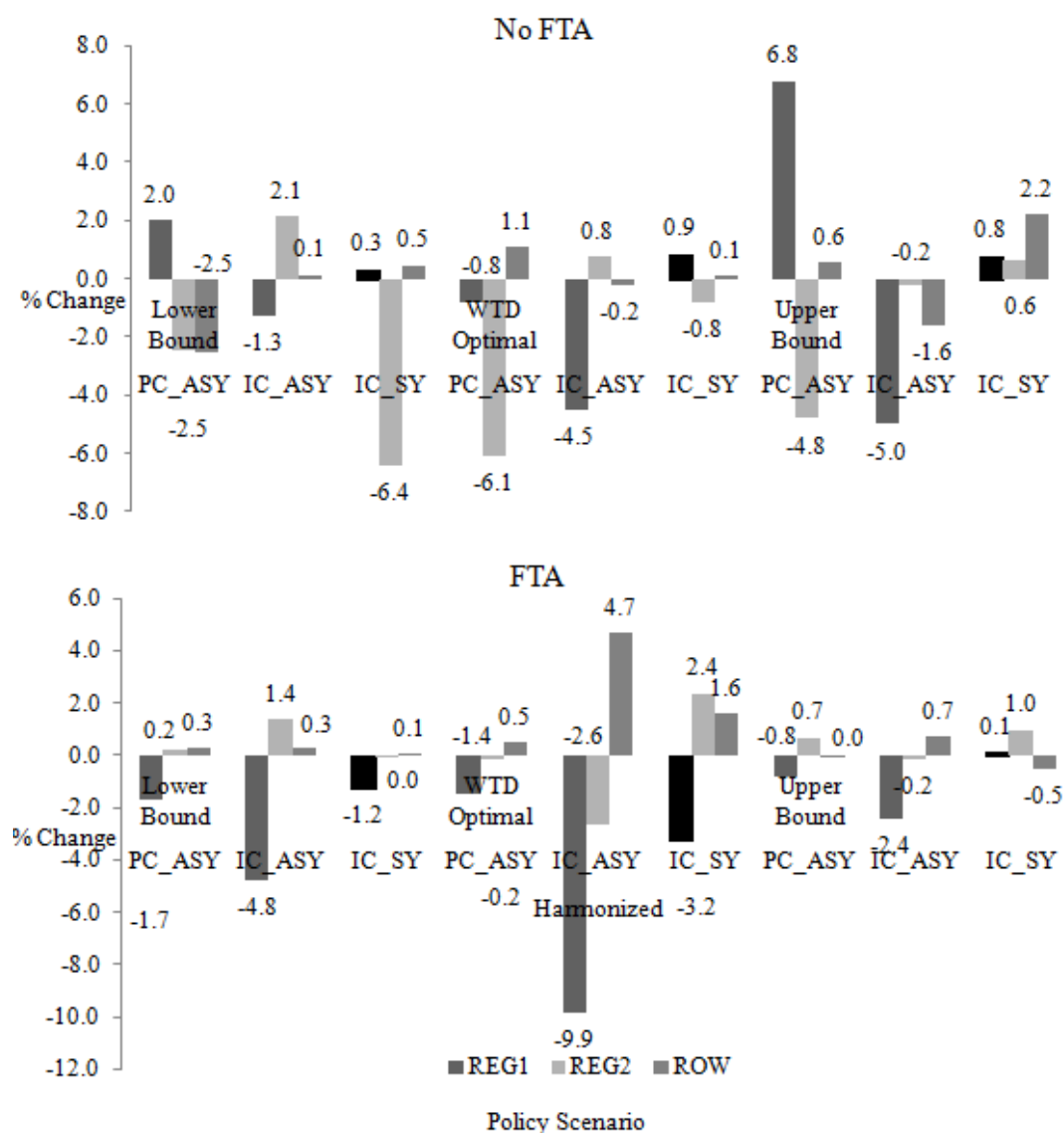
If instead, environmental taxes are harmonized, Figures 7.2 and 7.2B illustrate how welfare responses are comparable across market structures. According to Table 7.2A, In the absence of free trade welfare effects under the real wage assumption range from -6.7 to 6.8 percent when regions are asymmetric and -6.4 to 2.2 percent when they are symmetric.

Figure 7.2A indicates that when regions are asymmetric, harmonization in the presence of real wage rigidities is generally welfare worsening if not combined with free trade. In case of the EU, this is especially true when markets are perfectly competitive. In contrast, Canada's losses are higher under imperfect competition. For instance, Canada's welfare is higher than the baseline when minimum taxes are applied in a perfectly competitive setting. In contrast, welfare falls by falls by 6.7 percent when markets are imperfectly competitive. This occurs despite the relative cost advantages from harmonizing with a lower tax region. The gap in results between the two market structures is due to changes in cost and competitive advantage induced by changes in scale economies. For the below minimum harmonized taxes, welfare falls because pollution higher than the initial equilibrium and competition arising from relatively lower prices reduces efficiency gains. Further, lower output associated with the weighted optimal tax results in a modest welfare loss of 0.8 percent under perfect competition but a larger loss of 2.6 percent under the alternative market structure.

Assuming instead, that markets are imperfectly competitive, Figure 7.3 demonstrates that Canada experiences significant welfare losses under all tax scenarios. First, because the harmonized scheme reduces the region's production costs relative to the baseline, pollution under minimum, weighted optimal and above optimal scenarios is higher by 1.2 and 4.6 percent. However, the welfare gap between the two market structures arises because relatively lower production costs result in the reallocation of resources from the services sector to the energy sector. The adverse welfare effect from the upper bound tax derives from

the fall in scale economies in the transport, manufacturing and services sectors. The latter outcome puts firms in these sectors at a competitive disadvantage hence the contraction in welfare of 5.2 percent. This result contradicts theoretical conclusions by Gallegos (2012) and Keen et al. (2002) who contend that tax harmonization the smaller region is always welfare improving.

Figure 7.3: Welfare Effects of Harmonized Taxes under the Fixed Wage Closure



Likewise, harmonization in the presence of real wage rigidities generally results in welfare losses for the EU especially when the policy is not combined with a removal of border taxes. In addition, the results suggest that under these conditions the region's welfare out-

comes are not as sensitive to market structure. According to Figure 7.3 welfare losses occur under all tax scenarios save the minimum harmonized tax/imperfect competition scenario. Welfare costs are however lower when markets are imperfectly competitive suggesting that favorable changes in market structure can cushion regulatory costs even when trade is not liberalized.

Relaxing the restriction on trade results in lower welfare costs; however, as indicated in Figure 7.4, free trade fails to offset the negative effects of harmonizing with a lower tax region. It actually reverses the gains associated with a minimum harmonized tax observed under the alternative trade assumption. The welfare change is  $-2.6$  percent compared to  $3.1$  percent. Logically, free trade offsets the cost disadvantage from harmonizing with a higher tax region, however, because the region loses its competitive advantage in capital goods, the region's equilibrium capital and investment fall. Therefore, output falls by  $1.2$  percent. Welfare falls in The EU mainly due to output effects because the region's market structure does not significantly change under harmonized taxes. The contrast here occurs because in the absence of free trade the user cost of capital falls, hence aggregate output is  $4$  percent higher.

When paired with a region of similar size, the EU's welfare changes are smaller under both no free trade and free trade scenarios. The most significant change occurs when the minimum harmonized tax is applied in the absence of free trade. In this case the EU's welfare falls by  $6.4$  percent relative to the baseline. While harmonizing with NAFTA puts the region at a cost disadvantage, the difference is much lower compared to the Canada-EU case. However, welfare contraction is directly linked to the fall in aggregate output. In the case of NAFTA, welfare effects under both trade assumptions are minor. Results therefore suggest that harmonization between regions of similar size results in negligible welfare changes. This outcome clearly illustrates that the relative size of cooperating partner is an important determining of regulatory policy outcomes.

Figure 7.3 depicts changes in welfare when wages are fully flexible. Beginning with the no FTA scenario illustrated in the upper panel of Figure 7.4, the results suggest that

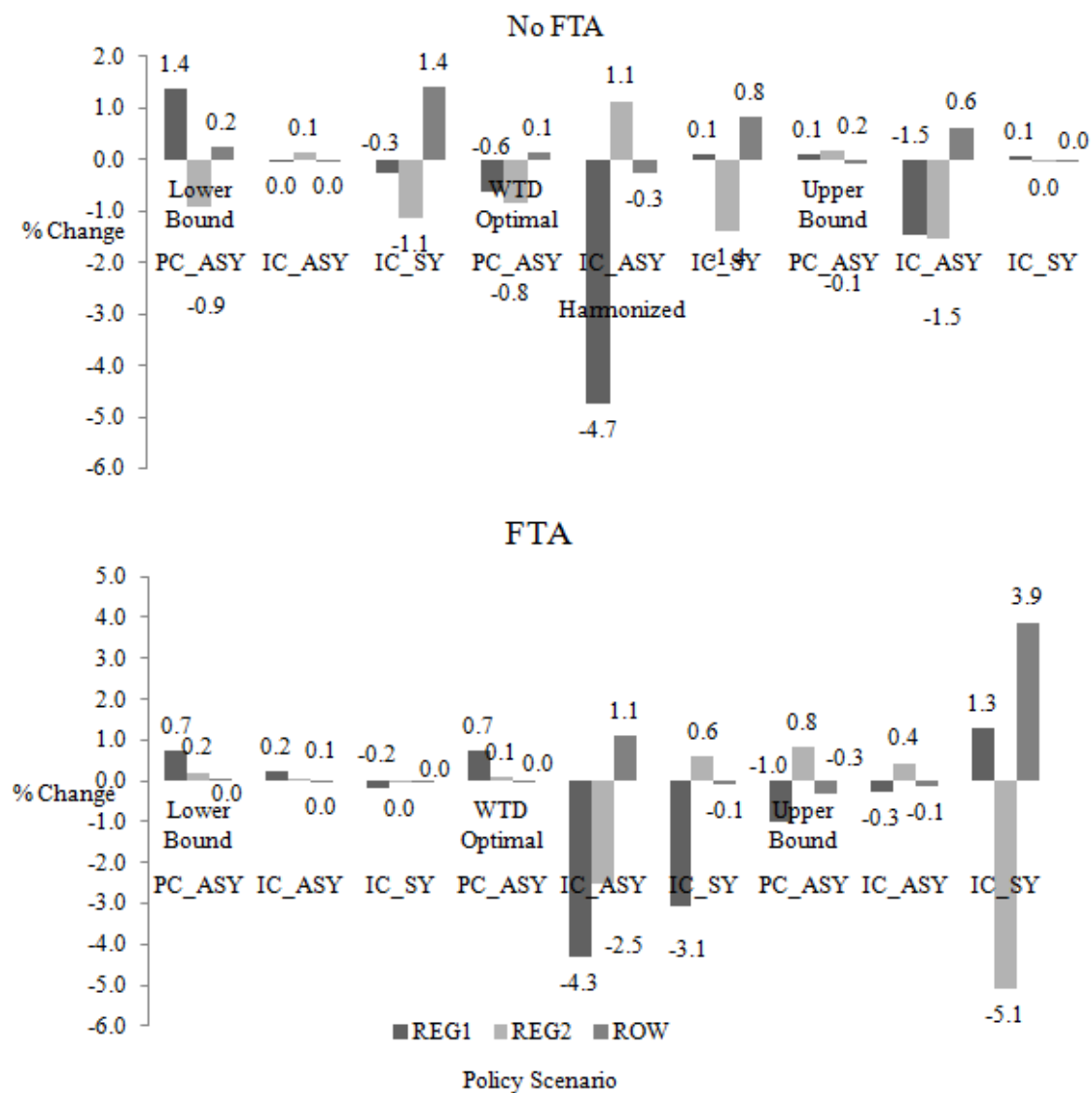
for positive coordinated environmental taxes, Canada's welfare falls under both perfect and imperfect competition. Nevertheless, the region's welfare responses are stronger when commodity markets are imperfectly competitive. For instance, the loss associated with an optimal coordinated tax is 0.6 percent under perfect competition and 1 when markets are imperfectly competitive. Similarly, the welfare gain under the above optimal tax scheme is 1.7 percent under perfect competition and 1.9 percent under the alternative market closure. The effects of free trade presented in the lower panel of Figure 7.3 suggest that regulatory effects under free trade are not sensitive to market structure. This is because free trade reverses welfare gains under the optimal tax scheme when markets are perfectly competitive but has minor effects under imperfect competition. On the contrary, when taxes are above optimal, free trade has minor effects under perfect competition, but reinforces gains under imperfect competition as shown by the 5.6 rise welfare. Overall, free trade has mixed effects on Canada.

For positive values of environmental taxes, the EU's welfare is lower than the baseline regardless of market structure. The most significant loss in welfare is associated with the above optimal tax when markets are imperfectly competitive. The rest of the policy scenarios result in minor welfare changes under both perfect and imperfect competition. The welfare loss associated with the above optimal tax is the net effect of a 1.9 percent fall in aggregate output and a 3.2 percent fall in pollution. The latter partially offsets the welfare loss from lower output. The loss is significantly higher under imperfect competition because induced changes in market structure increase the distortionary effect of market power.

Results in the lower panel of Figure 7.3 reveal that free trade more than offsets welfare losses under imperfect competition. Welfare is 1.1 and 1.8 percent higher under optimal and above optimal tax schemes respectively. These results seem to suggest that while free trade reduces both market power and scale efficiencies, efficiency gains from reduced market power more than offset efficiency losses from the reallocation of scale economies. Drawing comparisons with results under the fixed wage closure, this outcome implies that when the economy is at full employment coordinated environmental taxes can result in positive gains for the EU if combined with free trade. These results also reveal that, when wages

are flexible, market structure is not an important determinant of how free trade affects regulatory outcomes, the EU.

Figure 7.4: Welfare Effects of Harmonized Taxes under the Flexible Wage Closure



When paired with a region of similar size, the EU's welfare changes are smaller under both no free trade and free trade scenarios. The most significant change occurs when the minimum harmonized tax is applied in the absence of free trade. In this case the EU's welfare falls by 6.4 percent relative to the baseline. While harmonizing with NAFTA puts the region at a cost disadvantage, the difference is much lower compared to the Canada-EU case. However, welfare contraction is directly linked to the fall in aggregate output.

In the case of NAFTA, welfare effects under both trade assumptions are minor. Results therefore suggest that harmonization between regions of similar size results in negligible welfare changes. This outcome clearly illustrates that the relative size of cooperating partner is an important determining of regulatory policy outcomes.

Assuming no free trade, results indicate that Canada experiences minor losses in welfare when markets are perfectly competitive. Under the alternative market structure, the region experiences significant welfare changes. Case in point, welfare resulting from a minimum tax is 2.1 percent higher than the baseline under imperfect competition compared to 0.2 percent lower when markets are perfectly competitive. Similarly, under the weighted optimal tax scheme, welfare falls by 4.5 per cent when markets are perfectly competitive compared to 0.3percent under the alternative market structure. This contrast extends to the free trade scenarios. For instance, the welfare gain under imperfect competition is 3 percent higher than the perfectly competitive case. Likewise, the gap in welfare between imperfect and perfect competition is 7.3 percent under the weighted scheme and  $-2.5$  percent under the above optimal scheme. The region loses under the above optimal scheme despite the cost advantage of harmonizing with the EU because that the removal of trade barriers induces entry, because of this, the reallocation of scale economies results in lower welfare as oligopolistic rents fall. In addition to market changes, welfare falls because pollution is 3.9 per cent higher and employment falls by 7 and 2 percent under the skilled and skilled labour categories.

Finally, NAFTA's welfare changes are not sensitive to trade assumptions under the flexible wage scenario. In particular, changes are negligible in the absence of free trade but significant when above minimum harmonized taxes are applied under free trade. According to Figure 7.4, the region's welfare changes associated with weighted and upper bound harmonized environmental taxes are 0.2 and 0.0 percent respectively in the absence of free trade and  $-3.1$  and 1.3 percent when trade taxes are removed.

## 7.5 Conclusion

The preceding discussion reveals that the two regulatory approaches have different effects under the two market structures. Expressly, when markets are perfectly competitive, harmonized environmental taxes between asymmetric regions significant costs on the EU. In contrast, coordinated taxes have adverse effects on the region's output when markets are imperfectly competitive. The different results between the two market structures lend support to the arguments in favour of harmonization of taxes in imperfectly competitive markets. In the case of Canada, it is difficult to establish an association between market structure and regulatory outcomes. Overall, predictions of harmonized taxes are consistent with recent literature that regulatory effects are more pronounced under imperfect competition.

The effect of free trade on regulatory outcomes depends on the relative size of trading partners and market structure. When regions are asymmetric, the EU unambiguously gains from combining coordinated regulatory taxes with free trade. Results for Canada are mixed. In fact, free trade worsens regulatory outcomes when taxes are coordinated under perfect competition. The results suggest that generally, Canada does better by combining environmental taxes with no free trade. When regions are symmetric, simulations predict that output effects for both the EU and NAFTA are small. In the case of NAFTA, output changes are inconsequential. In fact, the unregulated region is more sensitive to regulatory choices of the other regions.

# Chapter 8

## Summary and Conclusion

*“of a small spark, a great fire”*

Proverb

### 8.1 Introduction

In this thesis, I have quantified and compared effects of coordinating and harmonizing corrective taxes on polluting intermediates. The research design draws from various strands of literature. First, specification of the optimal tax departs from the standard Pigouvian framework by incorporating labor market considerations. In particular, the tax specification draws from the double dividend literature. The double dividend literature highlights the pitfalls of ignoring the existence of tax-induced labor market distortions. Scholars following this research orientation argue that applying optimal taxes based solely on marginal external damages can worsen labor market distortions and result in net welfare losses. Because in any given economy, government revenue derives mainly from labor taxation, these arguments warrant specific attention in environmental policy design. For this reason, I adopt Bovernberg et al.’s (1998) specification of the second best optimal environmental tax on polluting intermediates. Bovernberg et al.’s specification adjusts marginal external damages by a measure of labor market inefficiencies, the MCPF. As a point of departure, I model the tax empirically.

Following the observation that a small set of intermediate inputs account for a large percentage of production generated emissions, I model emissions resulting from the use of six intermediate inputs.<sup>1</sup> Three energy (coal products, petroleum, and gas) and three non-

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<sup>1</sup>See Benarroch and Weder (2006), Dessus et al. (2002), Rothenberg and Poterba (1999) and others

energy intermediates (metals, chemicals and pulp and paper). The literature also suggests that intermediate inputs account for 45 percent of value added and 56 percent of global commodity trade flows. Increasing the user cost of polluting intermediates not only targets the source of emissions but is also likely to affect incentives directly. This point is important because the overarching objective of this research is to demonstrate how trade linked regulatory policy can restructure incentives in favor of participation.

Further, given that no study attempts to quantify and compare the effects of harmonizing and coordinating taxes on polluting intermediates, I draw on ideas from the tax harmonization literature. Specifically, Behrens et al. (2007) and Keen et al. (2002). From this body of work, I consider harmonization on the basis of destination. Additionally, anchor my analysis on individual studies on environmental policy harmonization (Cheikbossian, 2010; Turunen-Red and Woodland, 2004); Vlassis, 2012) and coordination of environmental policies by Hoel (1997) and (2001).

Central to the debate on environmental policy and trade is the effect of regulatory policy on competitiveness. The understanding of competitiveness differs widely in the literature. In this body of work, I use two definitions of competitiveness: changes in net export flows under perfect competition, and changes in firm level profits under imperfect competition. Moreover, because the case for linking regulatory policy centers on the possibility of strategic behavior (Copeland, 2000; Ederington, 2010), I explore the rent seeking, burden shifting and pro-concentration arguments put forward by Kennedy (1994), Markusen et. al (1993) and van Long and Soubeyran (2005) respectively. In particular, I examine the validity of these arguments.

Finally, I use CGE analysis by extending the GTAP model (Hertel, 1997, Francois, 1998; Ronson, 2005, McDougal, 2005). I incorporate emissions from intermediate use, disutility from pollution and second best environmental emission taxes. Moreover, as a further departure from the standard GTAP specification, I define the real exchange rate as the numeraire. This mosaic of ideas generates the generates a number of important insights.

## 8.2 Findings

In the preceding chapters, I have simulated the effects of environmental policy harmonization and coordination by considering policy outcomes under perfect and imperfect competition, asymmetric and symmetric regions, and fixed wage and endogenous wage closures. The results show that the outcome of collective environmental policy depends on (a) the nature of trade ties (asymmetric and symmetric), (b) market structure and (c) labor market considerations. Also, results show that when trading regions are asymmetric, free trade unambiguously improves the policy outcomes of the larger region regardless of labor market dynamics or the nature of competition. However, in general, policy outcomes are significantly different in the presence of real wage rigidities and when the labor market constraints is removed. Specifically, the presence of fixed wage rigidities when trading partners are asymmetric tends to result in stronger policy outcomes. Similarly, compared to perfect competition, policy outcomes under imperfect competition are more pronounced. Moreover, policy between symmetric regions is less costly in terms of foregone output and welfare.

In extending literature of trade linkage and environmental policy cooperation, this thesis demonstrates that when taxes on polluting intermediates are used as regulatory instruments, the presence of free trade results in lower output losses and gains. Essentially, free trade dampens both negative and positive effects of collective regulatory policy. Results suggest that under perfect competition and fixed wages, harmonized taxes independent of free trade result in significant losses for the larger region. For the smaller region, results are highly sensitive to whether capital and the regulated inputs are complements or substitutes; this result lends support to Fullerton and Heutel (2007) who contend that regulatory outcomes depend on substitution between the regulated input and capital and labor.

In the case of asymmetric regions competing under imperfect competition, regulatory costs in terms of forgone output are lower when coordinated environmental taxes are combined with free trade. Further, In the presence of real wage rigidities, the larger region gains more output by combining coordinated taxes with free trade. When the assump-

tion of asymmetry is relaxed, output effects of coordinated taxes are generally negligible. However, the EU experiences significant output changes when environmental taxes are harmonized, especially when they are applied in the presence of fixed wages. In essence results suggest that if unemployment is of concern, the EU does better by combining coordinated taxes with free trade when it trades with a symmetric region or coordinating taxes with a region of similar size. For NAFTA output effects are generally negligible.

The literature presented in chapter 2 indicates that the discussion of the effects of regulatory policy on trade and competitiveness are inconclusive. While earlier studies (Tobey 1990; Jaffe et al. 1995, van Beers and van den Berg, 1997) maintain that there is no significant relationship between regulatory policy and trade flows/competitiveness, recent studies (Ederington and Minier, 2003) have questioned these propositions and have found a strong link between policy stringency and trade flows. Findings in this research indicate that in the absence of free trade, effects of regulatory policy are negligible. They confirm, however, that at the sectoral level, trade flows of non energy industries are sensitive to regulatory choices. Under free trade, trade flows are more sensitive to policy changes; however outcomes are largely due to the sensitivity of trade flows to border taxes. Nevertheless, results suggest that policies combining free trade and environmental regulation improve the EU's trade flows at the expense of its trading partner under both asymmetric and symmetric trade link assumptions.

The question of competitiveness largely depends on the definition of competitiveness. In this research I define competitiveness on the basis of firm level activity and market structure. Specifically, I consider competitiveness with respect to changes in firm markups and market share. Based on this definition, results indicate that regulatory policy has significant effects on competitiveness and market structure. However, changes do not follow a predictable pattern. This is because outcomes are based on the complex interaction between regulatory policy, direct costs and induced effects through changes in economies and demand elasticities. A few key insights do emerge from the results; when regions are symmetric effects of regulatory policy on competitiveness and market structure are stronger. Expressly, shocks in Canada affect the structure of almost all sectors, including key manufacturing

and service sectors. Sectoral shifts indicate that contraction in petroleum production in the larger region results in expansion in the smaller. Further, in almost all cases, the energy sectors are most sensitive to regulatory policy. For the symmetric case, market structure effects are less pronounced and are mainly limited to the three energy sectors.

Net welfare effects are based on a combination of output, pollution, trade and market structure effects. Under perfect competition welfare effects are mostly driven by the output effect and are thus more predictable. In contrast, welfare effects under imperfect competition are more difficult to generalize. In essence, welfare effects in this thesis are dependent on market structure, country size, regulatory approach and labor market considerations. When regions are asymmetric, harmonizing taxes independent of free trade has adverse welfare effects when the real wage for the unskilled labor category is fixed, especially for the larger country. Further these effects are more pronounced under perfect competition. Results suggest that for this region, real trade unambiguously improves welfare outcomes under harmonized taxes. In contrast, efficiency gains from free trade do not always result in welfare gains for the smaller region, especially when markets are imperfect. Moreover, in the presence of real wage rigidities, free trade considerably reduces the welfare effects of coordinated taxes. In the case of symmetric trade ties, the largest welfare loss for NAFTA occurs when the upper bound harmonized tax is applied in the presence of free trade and endogenous wages.

Essentially, what this research demonstrates is that environmental policy design has to include market structure, region size and labor market considerations for it to be effective. In general, policies that combine taxes on polluting intermediates with free trade are less costly in terms of output foregone and welfare. Similarly, collective policy between regions (countries) of similar size is less costly. Real wage rigidities can have adverse implications for harmonized taxes, especially in the absence of free trade. For Canada, combining regulatory policy with free trade does not always reduce regulatory costs. Essentially, a region can lose from free trade if it results in the reallocation of resources from increasing returns such that it reduces real output. Finally, industrial organization considerations are important in determining collective policy outcomes and incentives.

### 8.3 Research Significance and Policy Recommendations

A number of important insights derive from this analysis. First, in the case of the EU-Canada CETA, the EU benefits from complying with the environmental provisions of the agreements in both the short and long-run. In contrast, joint regulation is likely to benefit Canada only in the long-run. It is possible for the region to experience significant regulatory costs in the short run. Second, because the regulatory costs between symmetric regions are small, Canada can do better by entering into joint policy with the EU as part of NAFTA, provided the degree of integration between Canada and the EU is high. Third, negligible regulatory costs for NAFTA suggest that there is scope for the broader application of regulatory taxes. Further, while free trade can result in perverse outcomes under the assumption of symmetry, regulatory costs are inconsequential. For this reason, joint policy with a region of similar size can be less costly for the EU.

Importantly, ignoring market structure effects can result in misleading policy recommendations. Finally, competitiveness changes are possible under a harmonized regulatory scheme. In particular, losses in competitiveness can occur under a lax regulatory stance because regulatory action induces changes in market structure. For this reason, rent-shifting arguments are questionable.

### 8.4 Limitations

While insightful, these findings are sensitive to parameter choices. Like any other CGE model, trade and substitution elasticities are important determinants of policy outcomes. Further, for the purpose of simplicity, I have only considered distortions from the environmental externality and labor taxes in specifying the regulatory instrument. However, the discussion in the literature review suggests that in the presence of imperfect competition, the second best optimal tax must take into account the distortion resulting from market power. Finally, imperfect competition results are highly sensitive to the specification of

imperfectly competitive behavior; because there is no specific model of new trade theories, small departures from these assumptions can result in very different outcomes. In this thesis, I have chosen the Cournot Oligopoly model because it is the most relevant and pragmatic specification for policy analysis.

## **8.5 Future Research**

The model used in this analysis is static, therefore inadvertently assumes that pollution does not build up overtime. In reality however, pollutants tend to have stock characteristics. Further because the interaction between costs and benefits of regulatory policy extend over a number of years, the results here can be more insightful if analyzed in a dynamic context. Here the specification of labor is rudimentary, future research will include an elaborate specification of labor market decisions. Differences between costs and benefits of regulatory policy extend over a number of years, the results here can be more insightful if analyzed in a dynamic context.

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