MACROECONOMIC EFFECTS OF LOW-INFLATION TARGETS AND DOWNWARD NOMINAL WAGE RIGIDITY IN A DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL

by
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ABSTRACT

During the past two decades, industrialized countries increasingly oriented monetary policy towards reducing and maintaining low inflation. A few of them, including Canada, adopted formal inflation targets. Like many other countries, Canada's formal adoption of inflation targets at the beginning of the 1990s coincided with an economic recession and subsequent sluggish recovery throughout the first half of the 1990s.

Some analysts have attributed this poor economic performance, relative to the United States, to the Bank of Canada's low-inflation policy. More recently, a number of empirical studies have further suggested that structural factors, including downward nominal wage rigidity, contributed to Canada's persistent high unemployment during the first half of the 1990s. Although the empirical literature shows evidence of these policy-induced *recessions*, there is no consensus on their magnitude or degree of persistence. The intellectual debate on low-inflation policy remains intense after nearly a decade of formal inflation targeting in many industrialized countries.

The thesis constructs an annual model based on the Bank of Canada's Canadian Policy Analysis Model (CPAM). In the context of this model, the thesis contributes to the current monetary policy debate by investigating how lowering the inflation target affects the level of economic activity in the short-run and in the medium- to long-run. The thesis extends the analysis by incorporating the downward nominal wage rigidity assumption into the model, and then investigates how downward nominal wage rigidity influences the macroeconomic effects of inflation reduction.

Lowering the inflation target reduces real economic activity in the short run, but has little effect in the medium- to long run. Setting the inflation target very low increases volatility in some sectors because achieving those targets requires relatively restrictive monetary policy. The assumption of downward nominal wage rigidity generally intensifies the recessionary effects of inflation reduction, particularly at low inflation rates. However, it does not appreciably affect macroeconomic stability.

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To My Parents, My Wife, and My Children

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CHAPTER 1: INTRODUCTION

During the past two decades, most industrialized countries adopted policies to reduce inflation. A few of them, including Canada, adopted formal inflation targets. Germany's inflation targeting dates back to the middle of the 1970s.[1] New Zealand, the United Kingdom, Sweden, Finland, Australia, Israel and Spain adopted formal inflation targets during the first half of the 1990s. Canada formally adopted inflation targets on February 26, 1991 following a joint announcement by the Bank of Canada and the Department of Finance to focus Canada's monetary policy on price stability. Other countries such as the United States and Japan, which have a history of relatively low inflation, continue to rely on a general qualitative commitment to low inflation.

Some analysts view the increasing commitment to price stability by a number of industrialized countries as the result of an emerging consensus that activist monetary policy leads to higher inflation in the long run without real output and employment gains. A number of intellectual developments and actual events corroborate this view. One of the earliest observations that contributed to this understanding relates to the long and variable lags with which monetary policy influences the real economy. According to Milton Friedman, " *We simply do not know enough to be able to recognize minor disturbances when they occur or to be able to predict either what their effects will be with any precision or what monetary policy is required to offset their effects.*"[2] In this regard, activist monetary policy could potentially exacerbate fluctuations in real output and employment.

Secondly, a decent amount of research on the long-run Phillips curve have produced results that do not corroborate the views previously held about the long-run trade-off between inflation and unemployment. In the long run, expansionary policies cannot

[1] Although Germany does not target inflation directly, the Bundesbank explicitly communicates the desired long-term path for inflation to the public, and sets targets for the growth rate of the Central Bank Money (CBM) accordingly.
[2] Milton Friedman (1968, p. 14).

generate higher output and employment by raising prices because businesses face capacity constraints and agents eventually build higher price expectations into future contracts. On the other hand, higher inflation tends to persist as agents build them into price expectations. In effect, attempts to exploit the short-run trade-off between output and inflation may result in higher inflation without the benefits of higher output and employment. The third intellectual development relates to the observation that agents' expectations about future monetary policy tend to influence the wage- and price-setting behaviour in the economy. This *time-inconsistency problem* is based on the view that policymakers who care more about output than inflation performance will try to pursue monetary policy that is more expansionary than expected. However, such a policy cannot produce higher output on average because agents eventually learn the monetary authority's strategy and adjust their inflation expectations accordingly.

Finally, low-inflation policy is generally perceived to promote economic efficiency, especially when it involves formal inflation targets. A low-inflation target can improve economic efficiency for a number of reasons. First, it improves credibility, particularly for central banks that have not successfully produced low inflation in the past. A credible inflation target anchors inflation expectations and thereby reduces the cost of economizing on non-interest bearing money (the so-called shoe-leather cost of inflation). Secondly, it promotes more productive investment by preventing unproductive investments in inflation hedges. Thirdly it promotes efficient long-term contracts by reducing market uncertainties. Moreover, low-inflation targets reduce the misallocation of capital that arises from the interaction of high inflation and a tax system that is not fully indexed. Some researchers have also produced evidence that lower inflation reduces inflation volatility and increases economic growth.

Although analysts frequently refer to inflation targeting as a monetary policy rule in the context of the conventional rule-discretion dichotomy, Bernanke, Laubach, Mishkin and Posen (1999) have argued strongly that in a practical sense, inflation targets are neither rules nor discretion. Rather, the authors refer to them as *constrained discretion* in the sense that on one hand, the explicit inflation targets increases accountability and therefore reduces the risks associated with the so-called time-inconsistency problem. On the other hand, the inflation-targeting framework improves discretion by allowing the target to be specified as a range, by distinguishing between temporary and permanent inflationary pressures and allowing monetary policy to respond to them differently, and by similar features that the framework can conveniently accommodate. In their words, " *by imposing a conceptual structure and its inherent discipline on the central bank, but without eliminating all flexibility, inflation targeting combines some of the advantages traditionally ascribed to rules with those ascribed to discretion*." The experience of most inflation-targeting countries clearly demonstrate the usefulness of constrained discretion, particularly for central banks that did not have the benefit of good record on inflation control prior to adopting inflation targets.

After nearly a decade of low-inflation policy in major industrialized countries, there are still important questions to answer regarding the optimum inflation target and the exact nature of the costs and benefits inflation reduction impose on society. The literature associates the costs and benefits of inflation reduction with the design, timing and implementation of the policy. By implication, different countries may realize significantly different net benefits from inflation targeting. These issues underlie the on-going research to determine the design and strategy for implementation that produce maximum net benefit to society. In general, the current monetary policy debate focuses on clarifying the appropriate definition and measurement of policy targets, the role of transparency and accountability in the design of modern monetary policy, and the appropriate degree of flexibility in pursuing the inflation targets. In Canada, researchers have paid particular attention to such issues as the optimum monetary rules for low-inflation targeting, the effects of low inflation on economic behaviour, and the implications of changes in economic behaviour for efficient monetary policy rules. More recently, researchers are devoting increasing attention to structural factors such as downward nominal-wage rigidity and non-linearities in the output-inflation trade-off, and what these structural features imply for the formulation of efficient monetary policy rules.

A number of countries, including Canada, originally announced *price stability* (i.e. zero inflation) as the ultimate goal for monetary policy. In his 1988 Hanson Lecture that inaugurated low-inflation policy in Canada, Governor Crow argued that price stability would be more credible, and hence more efficient (and productive) than any policy that involves some positive rate of inflation.[3] Both price-level targets and inflation targets imply a targeted path for the price level. However, the latter allows the price level to change over time because it does not require misses on the inflation target to be offset in the future. On the contrary, price-level targeting does not allow such "base drifts". In practice, however, these countries have invariably pursued positive inflation targets rather than price-level targets due to practical considerations including potential errors in measuring the target variable and concern for stability of real output and employment growth in the face of destabilizing aggregate supply shocks.[4] The general acceptance by central bankers (at least in practice), of some positive inflation corroborate the view expressed by Alan Greenspan, chairman of the US Federal Reserve System. According to Greeenspan (1989), price stability does not mean literally zero inflation. Rather, it should refer to price levels sufficiently stable as not to make expectations of change a major factor in key economic decisions.

The Bank of Canada exercised caution and explored conventional wisdom in pursuing its monetary reforms. As in the case of New Zealand which adopted formal inflation targets one year ahead of Canada, the Bank of Canada engaged in a prolonged campaign between 1988 and 1991 to educate the public on the virtues of price stability before it ultimately adopted inflation targets on February 26, 1991. Consequently, Canada, like most other inflation-targeting countries, formally adopted inflation targets after substantial disinflationary pressures were already evident. The effective communication of the

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[3] Crow (1989, p. 21-24)

[4] Inflation measures typically have a net positive bias because of innovations and changing tastes. Crawford (1993) estimates the bias in Canada's CPI inflation within 0.5 percent at an annual rate. Similar estimates in the United States put the positive bias in the CPI inflation between 0.5 to 2.0 percent at an annual rate. See Shapiro and Wilcox (1996).

Bank's future policy reduced uncertainty about the course of monetary policy and allowed the public to adjust inflation expectations in a way that may have reduced the potential recessionary effect from the policy. Moreover, the Bank of Canada jointly announced the inflation targets with the then Minister of Finance, Michael Wilson. This gesture created a general perception of close cooperation between the two entities that could influence monetary policy in the country, and therefore boosted credibility of the Bank's policy.

Since the public generally understands, uses, and forecasts the Consumer Price Index frequently, the Bank of Canada chose the consumer-price inflation as the target variable in order to improve transparency and accountability. The new monetary policy framework gained further credibility from the existing institutional arrangement where the entity that measures the consumer price index (Statistics Canada) is independent of the Bank of Canada who implements the targets and assesses past performance. The Bank of Canada took further steps to improve transparency and accountability, including the publication of the Monetary Conditions Index (MCI) to serve as an indicator of monetary policy stance to the public. The Bank also modified its *Annual Report* to provide more non-technical information to the public including reviews of monetary policy and the success of inflation targeting. The Bank undertook similar innovation in its quarterly Monetary Policy Report, including the publication of monthly supplements.[5, 6]

In countries like Germany and the United Kingdom which specify their policy as point targets, substantial output losses can occur when the economy experiences negative supply shocks. The Bank of Canada deals with this problem by stating its inflation target as a range rather than a point target, often with greater emphasis placed on the bands than on the midpoint. The Bank of Canada engages in further discretion by paying attention to the differences between inflation in the Consumer Price Index and the underlying trend

[5] The monetary conditions index is a weighted sum of changes in the ninety-day commercial paper interest rate and in the Group of Ten trade-weighted Canadian dollar exchange rate; the weights are three to one.
[6] To the extent that the Bank of Canada uses discretion in deciding how to respond to various inflationary impulses in the economy, the Monetary Conditions Index may not correctly predict monetary policy. In this regard, some analysts have criticized the Bank of Canada for publishing the MCI, and have called on the Bank to discard it. See Mishkin (2000).

inflation that excludes food and energy prices - two components of the CPI that are most volatile, and whose short-term dynamics often do not reflect structural factors in the domestic economy. The distinction between the two inflation measures allows the Bank to avoid reacting to erratic short-term movements in the target variable without compromising its credibility. The substantial operational flexibility has led some analysts to view Canada's inflation targeting as "a way to help dampen cyclical fluctuations in economic activity"[7].

In some countries, for example New Zealand, consensus emerged rapidly about virtues of the monetary reforms, including the adoption of formal inflation targets. Therefore, the monetary policy debate focused on implementation and control problems. In other countries such as the United Kingdom where the central bank was not completely responsible for setting the monetary policy instrument, the Bank of England was not subject to a great deal of criticism.[8] Contrary to the experience in these countries, the Bank of Canada faced intense criticism for focussing monetary policy on inflation control and for setting low inflation targets. Drawing powerful arguments from the economic recession that coincided with the introduction of the policy reform, and the sluggish recovery that lasted nearly half of a decade, critics made a case for reducing the Bank of Canada's autonomy.

Indeed, the empirical literature shows evidence that inflation reduction causes some output and employment loss. However, it does not indicate a consensus on the magnitude or persistence of these costs. Most analysts tend to view the costs to be relatively short lived and the benefits to last must longer. As this chapter indicated earlier, the literature shows that the specific approach adopted in designing the policy framework goes a long way to determine the nature of costs and benefits that arise from inflation reduction.

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[7] Mishkin and Posen (1999)

[8] Gordon Brown, the Chancellor of the Exchequer for a newly-elected Labour Government granted operational independence to the Bank of England on May 6, 1997. The government, however, retained a "national interest " clause that would allow it to overrule the Bank's policy if it deemed such action necessary. See Bernanke et.al. (1999).

Some analysts have also raised concerns about the potential for structural factors to intensify and prolong economic recessions in a low-inflation environment. In this context, analysts have particularly stressed the potential effects of downward nominal wage rigidity and possible non-linearities in both the short-term and the long-term Phillips Curves.

This thesis contributes to the clarification of the ways in which downward nominal-wage rigidity influences the output-inflation trade-off. Based on earlier research, it assumes that the Canadian labour market exhibits some degree of nominal-wage rigidity.[9] It incorporates the downward nominal wage rigidity assumption into a relatively large and sophisticated macroeconomic model, and then uses the model to study how inflation reduction affects real output and employment, with and without the assumption. The model is a simplified, annual version of the Canadian Policy Analysis Model (CPAM), a quarterly model used by the staff at the Bank of Canada for policy analysis.[10] In the rest of the thesis, *the Model*, or *the Baseline Model* refers to the version of the model that does not incorporate the downward nominal-wage rigidity assumption, and *the Nominal-Wage Rigidity Model* refers to the version that incorporates that assumption. The model introduces the downward nominal wage rigidity assumption in chapter 6. The discussion in chapters 1 to 5 refers exclusively to the baseline model.

The rest of the thesis is arranged as follows: Chapter 2 contains a brief survey of the pertinent literature.[11] Chapter 3 describes the structure of the model without the downward nominal wage rigidity assumption (i.e. the baseline model). The thesis calibrates the model. Macroeconomists are increasingly relying on the calibration method to parameterize their general equilibrium models because of potential difficulties

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[9] See Fortin (1996), Cameron, Simpson and Hum (1998), and Crawford and Harrison (1997). Crawford and Harrison cautioned that this phenomenon may not be significant at the aggregate level for a number of reasons. Chapter 6 discusses the theoretical and empirical literature on this topic.

[10] See Black and Rose (1997). CPAM incorporates the key properties of the larger and more disaggregated Bank of Canada's New Quarterly Projection Model (QPM). See Duguay and Longworth(1997); Poloz, Rose and Tetiow(1994) ; Black, Laxton, Rose and Tetlow(1994); and Coletti et. al (1996).

[11] Chapter 6 extends the literature review to cover theoretical and empirical discussion on downward

associated with estimating the large number of parameters involved. Chapter 4 discusses the calibration of the model and derives the structural shocks required to perform stochastic simulations in chapters 5 and 6. Chapter 5 discusses simulation results on the effect of reducing the inflation target from 7 percent to one percent at two percentage-point intervals based on the baseline model. Chapter 6 incorporates the downward nominal wage rigidity assumption into the model, repeats the simulation exercise in chapter 5, and compares the results with those derived in chapter 5 based on the baseline model. Chapter 7 contains the summary, conclusions and extensions for the thesis.

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nominal wage rigidity.

CHAPTER 2 A SURVEY OF THE LITERATURE

Economic analysts have little difficulty justifying a policy that reduces inflation from high levels; for example, 20 percent, 30 percent or 50 percent. Research and real events show that high inflation imposes real cost on society through several avenues. High inflation causes the financial system to expand excessively as agents try to find inflation hedges. English (1996) shows that in the United States, a 10 percent increase in the inflation rate would increase the share of GDP produced in the financial sector by approximately 1.5 percentage points. Furthermore, inflation produces a fragile financial system since financial institution must obtain, and frequently update, large volumes of information. High inflation causes excess volatility in prices, distorts relative prices and reduces efficiency in all markets. Hall, Walsh and Yates (1997) find that time-dependent pricing rules are more widespread among U.K. companies than state-dependent pricing rules. Therefore, high inflation rates can significantly distort relative prices and reduce market efficiency. Moreover, high inflation increases the cost of doing business since businesses have to monitor and revise prices frequently. High inflation reduces the value of savings, and thereby reduces the incentive to save. Moreover, high inflation imposes excess taxes when tax brackets are either not indexed or only partially indexed. Feldstein (1996) estimates that a two-percentage points increase in the inflation rate from 2 percent to 4 percent may reduce real GDP in the United states by 2.0 percent annually given the imperfect indexation of the tax brackets. Although the individual sources of cost described above may be small, the overall effect on the economy can be very significant. Thus, there is a strong case for inflation reduction when the rate of inflation is high.

On the other hand, it is difficult to justify a policy that reduces inflation from moderate or low levels. For example, Barro (1995) finds little relationship between inflation and economic growth at inflation rates below 10 percent although he shows evidence that higher inflation rates significantly hinder economic growth. Judson and Orphanides (1996) and Sarel (1996) reach similar conclusions. This distinction is important given the fact that whereas most countries experienced high inflation rates in the 1970s and 1980s, most industrialized nations had reduced their inflation to moderate or low rates by 1991. It stands to reason, therefore, that central banks that adopted formal inflation targets expected benefits other than large output and employment gains. For example, New Zealand was running inflation below 6 percent for three consecutive years before it formally adopted inflation targets in March 1990. Canada was running 4-5 percent inflation during 1986-1991, and had actually brought it down to 3 percent by 1990, before it formally adopted inflation targets in February 1991. Similarly, the United Kingdom had brought inflation down from a peak of 12 percent in 1990 to about 3 percent by the time it formally adopted inflation targets in October 1992.[12] Johnson (1990) suggests that most of the inflation targeting countries were historically relatively high inflation countries; therefore the real gain for the inflation-targeting countries is, perhaps, the nominal anchor the inflation targets provided for inflationary expectations.

The aggregate data reflect the net cost (or net benefit) from disinflation. When monetary policy focuses on keeping inflation low, the effort to manage inflationary pressures to that end may result in a relatively tight monetary policy and high interest rates. Fortin(1996), for example, provides some evidence for Canada, showing that the Canada-U.S. real short-term rate differential averaged 3.6 percent between 1989 and 1996 compared with 0.9 percent over the period 1980-88. The higher interest rates raise the cost of borrowing, and thereby reduce private-sector investment and consumption expenditures. In a study on how a permanent change in inflation affects the user cost of capital in the United States, Cohen, Hasset and Hubbard (1997) concludes that inflation significantly increases the user cost of capital even at the existing level of about 4 percent. They also note that a percentage-point reduction in inflation results in a larger marginal investment gains when inflation is low. The decline in aggregate demand due to lower investment and consumption expenditures reduces real output and employment, resulting in the so-called "*recession effect*" [13] from inflation reduction. Moreover, the lower real investment expenditures cause a cumulative decline in the stock of capital and produce a "*capital*

[12] Bernanke, B. et. al. (1999)

[13] See Simpson, Cameron and Hum (1996).

stock effect" that tends to prolong the decline in output and employment.

Higher interest rates also increase the cost of servicing the public debt. When the policy succeeds in keeping inflation low, the lack of adequate increase in the general price level may inhibit smooth adjustment of relative prices, potentially increase nominal rigidities and create market distortions. There may also be interest parity problems when trading countries are not maintaining comparable rates of inflation at the same time. Although the empirical literature shows evidence of these policy-induced *recessions*, there is no consensus on their magnitude and degree of persistence.[14]

Proponents of low-inflation policy justify the policy on the basis of potential benefits that a credible low inflation regime can generate. These benefits include a potential increase in productivity due to improved resource allocation as agents eliminate the costs of inflation hedges (the so-called "*allocation effect"* of low inflation). There is also the potential for real output to grow faster due to increased efficiency in resource allocation (the so-called "*productivity growth effect*" of low inflation).[15] Society also benefits from less frequent financial transactions (lower shoe-leather costs); less frequent adjustment of prices (lower menu costs); lower costs from the interaction between inflation and unindexed (or partially indexed) tax system; less confusion between changes in relative prices and the general price level; and less uncertainty about future prices.[16]

A number of researchers have attempted to quantify the real effects of inflation reduction. In most cases, analysts measure the real effect of disinflation in terms of the *sacrifice ratio*. The sacrifice ratio measures the output (or employment) loss that a permanent one percentage-point permanent reduction in inflation imposes.[17] Using the Bank of Canada's

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[14] See Ragan(1998), O'Reilly(1998), Fortin (1996), Selody(1990), Howitt(1990), Meyer and Rasche(1980), and Feldstein(1979). Selody (ibid.) provides a good survey of earlier research on this topic.

[15] See Mansfield(1980). It has been difficult, however, to find strong empirical evidence to support the view that low inflation raises productivity growth. See for example, Cameron, Hum and Simpson, 1996.

[16] O'Reilly(1998) contains an extensive survey of the empirical literature. Selody (1990) surveys the earlier literature.

[17] Black, Coletti and Monnier (1998) have developed an alternative measure based on the concept of

early econometric model (RDXF), Selody (1990) calculates the sacrifice ratio for Canada to be 3.4. Howitt (1990) uses data from the 1981-82 recession and the subsequent recovery to estimate a sacrifice ratio of 4.7 for Canada.[18] Based on an equation that relates inflation directly to output gaps, Cozier and Wilkinson (1991) use an expectations-augmented Phillips curve over the period 1964-1988 to estimate Canada's sacrifice ratio at 2.0 using inflation measured by the GDP deflator. Ford and Rose (1989) estimate Canada's sacrifice ratio to be 2.6 percent based on two sample periods, 1967Q1-85Q4 and 1967Q1-81Q4. Ball (1994) estimates the Canadian sacrifice ratio during 1981-85 at 2.4. The above estimates put the pre-targeting Canadian sacrifice ratio in the range of 2.0-4.7. Palle Schelde-Anderson (1993) ranks Canada poorly (at tenth place) among OECD countries with respect to sacrifice ratios calculated to the 1980s.

Some analysts have argued that benefits from disinflation are relatively subtle, and therefore conventional estimates of the sacrifice ratio based on output and employment measures do not adequately reflect them.[19] There have been several attempts to quantify the benefits of inflation reduction. Using a partial equilibrium approach and allowing inflation to interact with the non-indexed tax system and distortions in money demand, Feldstein (1996) estimates that the benefits from a 2 percentage-points decline in inflation from 4 percent to 2 percent amounts to one percent of GDP each year.[20] Since these benefits accrue into the future, their present value could be very significant. An earlier work by Fischer (1981) estimated that a 10 percentage-point reduction in inflation from 10 percent to 0 percent would increase real output in the United States by 2 percent each year under similar circumstances. Bakhshi, Haldane and Hatch (1997) apply a similar method to the United Kingdom and find that a 2 percentage point reduction in inflation increases real GDP by 0.2 percent each year. Todter and Ziebarth (1997) estimates that a

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Equivalent Variation. However, the sacrifice ratio is, by far, the most popular measure.

[18] Although the estimates by Selody (1990) and Howitt (1990) cover the same period, the former assumes that part of the increase in unemployment that occurred after 1981-82 is attributable to factors other than monetary policy and therefore does not contribute to the cost of reducing inflation; the latter, on the other hand, includes all the increase in unemployment during and after the recession.

[19] See Christopher Ragan (1998).

[20] Although this estimate sums benefits from all major sectors of the economy - consumption, housing,

2.0 percentage-points reduction in inflation raises real output by 2.0 percent annually.

The review to date clearly demonstrates a lack of consensus on the empirical size of the net benefit society derives from policies that focus on inflation reduction. A survey of the literature by Black, Coletti and Monnier (1998) confirms that the wide variation in the empirical estimates discussed above characterizes the exiting estimates in general. The differences in these estimates reflect, among other factors, differences in inflation levels prior to the disinflation, the size and speed of the disinflation, and specific assumptions about structural factors including various elasticities and the way inflation interacts with the tax system. In the case where the monetary authority formally commits to pre-announced inflation targets, the sacrifice ratio will also be influenced by the extent to which the public perceive the announced policy to be credible, and the degree of discretion built into the design of the policy. O'Reilly (1998) notes that partial-equilibrium estimates of the (net) benefits of disinflation are sensitive to the specification of the money demand function. Similarly, estimates based on general equilibrium models depend on elasticity estimates, the calibration of the model, and assumptions about economic growth.[21]

The assumption analysts make about the aggregate relationship between price inflation and the unemployment rate (i.e. the properties of the Phillips curve) most likely account for a large portion of the differences between their estimates of the welfare effect of disinflation. Recent studies suggest a number of factors that may have influenced the inflation-unemployment nexus in Canada. Rose (1988), and Fortin (1989) suggest that changes to the unemployment insurance act, increase in payroll taxes, higher employment costs due to union power, and other developments during the 1980s may have raised the non-accelerating inflation rate of unemployment (NAIRU) between the 1980s and

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money demand and government debt, many analysts think it overstates the true benefits.

[21] Studies based on partial equilibrium analysis typically use the deadweight loss under the (compensated) demand curves for various sectors of the economy as proxy for the welfare loss due to higher inflation. For studies based on general equilibrium models, the parameters of the models are typically obtained from the literature and are usually calibrated to the economic characteristics of the country they are supposed to represent.

1990s.[22] Fortin (1991), Poloz and Wilkinson (1992), and Jones (1995) suggest that persistent actual unemployment may have exerted diminishing effect on inflation over time (i.e. unemployment hysteresis). Ricketts and Rose (1995), and Fillion and Leonard (1997) argue that changes in monetary policy strategy between the 1980s and 1990s may have changed the process by which agents form expectations about inflation and other relevant variables. Finally, the observation by Fortin (1996), Simpson, Cameron and Hum (1998), and Crawford and Harrison (1997) that wage settlements have different dynamics in moderate- and high-inflation periods than in low-inflation periods suggests that downward nominal wage rigidity may have shaped the Canadian output-inflation nexus in an important way.

Fortin (1997) tests and rejects all the above conjectures except for two: - a structural break for the period 1974-91, and nominal wage and price rigidities. Fortin (1996) argues that downward nominal wage rigidity has played an important role in Canada's experience with persistent high unemployment throughout the first half of the 1990s. The work by Fortin (1996, 1997), Simpson, Cameron and Hum (1998), and Crawford and Harrison (1997) set the stage for chapter 6, which incorporates the downward nominal wage rigidity assumption into the model to investigate the potential effect of this phenomenon on the output and employment effect of disinflation.[23]

Bernanke, Laubach, Mishkin and Posen (1999) consider whether the countries that adopted inflation targets did, in fact, lower their costs of disinflation relative both to their own past and comparable countries that did not formally adopt inflation targets. They calculate the sacrifice ratios for the four major inflation-targeting countries (New Zealand, Canada, the United Kingdom and Sweden) for disinflations prior to adopting inflation targets. Then, using as regressors the initial inflation level prior to disinflation, changes in inflation during disinflation, and the length of the disinflation period, they

[22] Fortin estimates that the NAIRU may have increased from 7.5 percent to over 9 percent during this period.
[23] Chapter 6 extensively reviews the theoretical and empirical literature on the causes and economic effects of downward nominal wage rigidity.

estimate a regression equation for the sample of sacrifice ratios. They use the estimated equation to forecast the counterfactual sacrifice ratio for each country's post-targeting period. The authors repeat the same process for five countries that have not formally adopted inflation targets (the United States, Australia, Italy, Germany and Switzerland), and compare the sacrifice ratios between the two groups. They find that for all the inflation-targeting countries except Sweden, the actual post-targeting sacrifice ratio was not only higher than the average level in previous disinflations but also higher than the forecast (counterfactual) sacrifice ratio. Among the five countries without formal inflation targets, Italy and the United States had similar characteristics as those for the targeting countries. However, Germany and Switzerland had lower sacrifice ratios in the 1990s than their respective forecast values as well as their respective averages in previous disinflations.

A number of studies have identified a positive relationship between the level of inflation and inflation uncertainty. Ball and Mankiw (1995) find inflation to be positively related to the skewness of the distribution of relative price changes; Ball, Mankiw and Romer(1991) show that average inflation, by influencing the interval between price changes, affects the output-inflation trade-off. Amano and Macklem (1997) find a relationship between inflation and the asymmetry in the distribution of changes in the relative producer price. Holland (1995) shows that higher inflation precedes increases in uncertainty but not the reverse; thus suggestion a causation from the level of inflation to inflation uncertainty. Ricketts and Rose (1995) find evidence of a systematic relationship between higher levels of inflation and higher inflation volatility among the G-7 countries. Evans and Wachtel (1993), Engel (1983), and Lucas (1972), among others, find similar relationships. To the extent that greater inflation uncertainty is costly to businesses and households, lower inflation produces benefits by reducing these uncertainties. Hess and Morris (1996) find that inflation uncertainty, variability of real growth, and relative price volatility rise together as inflation rises from low to moderate levels.

As discussed earlier in this chapter, studies based on the first half of the 1990s do not show that countries that adopted formal inflation targets benefited from lower sacrifice ratios.[24] For example, Debelle (1996) estimates the Canadian sacrifice ratio between 1981-85 at 2.0 percent. However, he obtained an estimate of 3.5 percent for the early post-target period (1990-93). Moreover, Canada's sacrifice ratio was higher than that of New Zealand, the other early inflation-targeting country. He attributes Canada's high sacrifice ratio to the tighter monetary policy necessary for the Bank of Canada to achieve credibility for a monetary reform that lacked the kind of institutional support enjoyed by the Reserve Bank of New Zealand.[25] However, this poor performance may only reflect the well-documented ostensible transitional cost of disinflation, especially when the central bank tightens monetary policy excessively in seeking to influence the public perception about policy credibility. Thus, the medium- to long-term cost of disinflation may reflect the net gain from inflation targeting better.

Bernanke, Laubach, Mishkin and Posen (1999) test for short-term gains from formal inflation targeting by comparing estimates of inflation rates and inflation expectations among inflation-targeting countries (New Zealand, Canada, the United Kingdom and Sweden) with those from the countries that did not formally adopt targets (the United States, Australia, Italy, Germany and Switzerland). They do not find evidence that inflation targeting reduces inflation variability or inflation expectation. It is important to note, however, that this study includes data up to only 1993, and therefore the results reflect short-term dynamics in the post-targeting period.

The model discussed in chapter 3 incorporates three important features from the empirical results discussed in this chapter. First, it incorporates an asymmetry into the short-term Phillips curve equation that determines trend inflation. The asymmetry causes trend inflation to respond more strongly to excess demand in the short run than it responds to

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[24] See Bernanke et. al (1999), and Debelle (1996) for example.

[25] New Zealand's monetary reform was accompanied by a fiscal reform that reduced the government deficits and effectively addressed the national debt. It was also accompanied by the Employment Contract Act aimed and eliminating labour unions and decentralizing wage contracts. The monetary reform also involved greater accountability, making the Governor of the central bank subject to possible dismissal by the government if the target was breached.

excess supply in the short run. In the long run, the trend inflation depends on expectational dynamics and external shocks channeled through the terms of trade; it does not respond to the output gap. Secondly, the model restricts the weight on the central bank's inflation target in agents' inflation expectations to only 20 percent. The small weight reflects the lack of significant difference in inflation expectations between the inflation-targeting countries and the non-targeting countries. Finally, the model incorporates the downward nominal wage rigidity assumption in chapter 6, and studies how that labour market imperfection affects the net benefit from inflation reduction through formal inflation targets.

CHAPTER 3: STRUCTURE OF THE MODEL

3.1 An Overview of the Model

The model represents a small open economy with a well-defined steady state. The structure is based on the Canadian Policy Analysis Model (CPAM), a quarterly model constructed by Richard Black of the Bank of Canada and David Rose of QED Solutions.[26] However, the model is unique in many important respects. First, it is an annual model while CPAM is a quarterly model. Second, the model rebuilds the structure for relative prices in the non-traded sector and simplifies the structure of relative prices in the traded sector. Third, the model simplifies the term structure of interest rates to make the interaction between the financial sector and the rest of the model, including the effects of monetary policy more comprehensible. The model also introduces a time-varying risk premium to make the model more realistic. Finally, chapter 6 extends the original model by incorporating the downward nominal wage rigidity assumption.

The model presents four major sectors: households, firms, the (consolidated) government, and the monetary authority. The supply side is endogenous in that firms choose the optimum levels of capital and labour. The principal components of aggregate demand are based on optimizing behaviour of agents. Financial intermediation is not formally modeled. Households act as if they own productive capital and government bonds directly, and directly engage foreigners in financial transactions. Fiscal and monetary policies are endogenous. Fiscal policy consists of choosing the desired national debt-to-output ratio using the personal income tax rate as instrument. Monetary policy consists of choosing a target inflation rate for the consumer price index, and using the slope of the yield curve as instrument to achieve this target. The dynamics of the model feature well-defined stock-flow relationships for key variables such as financial assets, the stock of capital, and human wealth. Most agents in the model form expectations in a rational or

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[26] Black, R. and David Rose (1997). The authors base the structure of CPAM on the Bank of Canada's Quarterly Projections Model (QPM). However, CPAM is much smaller and simpler than the QPM. The

model-consistent manner that also respects information from past experience.

The model reflects three levels of structural relationships, each of which constitutes a distinct *sub-model*: the ***steady state model***, the ***equilibrium model*** and the ***disequilibrium model***. The *steady-state model* abstracts from all forms of dynamic adjustments and solves for values that reflect the underlying stable, long-run state the economy attains when all types of shocks have completely worked themselves out. The ***equilibrium model*** represents medium- to long-term structural relationships. It is based on equations that add lags, leads and trends to behavioural equations in the ***steady state model***. Dynamics in the *equilibrium model* are limited to those that reflect intrinsic stock-flow relationships in the economy.

The third sub-model, ***the disequilibrium model***, reflects short-term dynamics in the economy. It is based on equations that add one or more of three types of adjustment terms to their counterpart equations in the ***equilibrium model***. The first type of adjustment reflect the gradual nature of agents' responses to shocks due to rigidities arising from such constraints as irreversibility of certain investment decisions and past contracts still in effect. The second type of adjustment reflects the fact that agents' expectations are partly adaptive and partly rational. Agents update their perception of the future and adjust their behaviour accordingly as they obtain more information. The third type of adjustment arises from endogenous reaction of monetary and fiscal policies to cyclical movements in the economy. The first type of disequilibrium adjustment receives the most elaborate treatment in the model. Agents choose the adjustment path of each choice variable to minimize two types of costs: the expected cost of being away from equilibrium, and the expected cost of adjusting towards equilibrium. Chapter 4 discusses these adjustment costs in detail, and calculates an adjustment term (*cadj*) which adds to every behavioural equation in the disequilibrium model.

The *steady-state model* solves independently for the steady-state values of the

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staff at the Bank of Canada have used both QPM and CPAM extensively for research and policy analysis.

endogenous variables. The ***equilibrium model*** and short-term ***disequilibrium model*** solve simultaneously for the equilibrium and disequilibrium values of the endogenous variables. The rest of the chapter fully documents the model. Section 3.2 presents the demand-side of the model; section 3.3 discusses the supply-side; and section 3.4 looks at the government sector and the channels of transmission for the endogenous fiscal policy. Section 3.5 models the external sector of the economy, and endogenously determines the equilibrium real exchange rate through the current account and the non-official capital account. Section 3.6 presents the structure of relative prices, and section 3.7 discusses inflation and inflation expectations in the context of the Phillips curve. Section 3.8 looks at monetary policy and the nexus of interest rates that transmit monetary policy to the rest of the economy. In many cases, the equation that determines the disequilibrium value of a variable immediately follows its counterpart equation in the *equilibrium model*. Appendix 5 produces mnemonics for the model variables, the parameters for the model, and the complete steady-state solution for the model.

3.2 The Demand Side of the Model

3.2.1 The Representative Agent's Consumption Function

The model makes a notional distinction between two types of consumers: *forward-looking consumers*, who base their consumption decisions on an intertemporal optimizing rule; and "*rule of thumb" consumers*, who spend all income they earn in each period. *Rule-of-thumb* consumers are assumed to earn 40 percent of total labour income; the remaining 60 percent accrues to *forward-looking* consumers. All incomes from financial assets accrue to *forward-looking* consumers. The sum of expenditures by the two types of consumers constitutes total consumption expenditures.[27] The consumption function for *forward-looking* consumers is derived as follows:

[27]Only the forward-looking type form expectations. Rule-of-thumb consumers receive a weight of $\Psi=0.4$ in the aggregate consumption function; Forward-looking consumers receive a weight of $(1-\Psi)=0.6$.

Individual forward-looking consumers maximize expected lifetime utility by choosing the desired level of consumption in each period, subject to a lifetime budget constraint. The expected lifetime utility (Ufl^e) in period t for a forward-looking individual of age a is given by

$$Ufl_t^e = \frac{1}{1-\theta} E_t \sum_{v=t}^{\infty} \delta^{v-t} cfl_{a+v-t,v}^{1-\theta} \tag{3.1}$$

where $cfl_{a,t}$ is the level of consumption chosen by a forward-looking individual of age a in period t, δ is the rate at which the individual discounts certain future consumption, and θ is the coefficient of relative risk aversion.[28,29,30]

Individuals do not know with certainty how long they will live, and as a result they discount future consumption by more than δ according to the perceived probability of death. Suppose the probability of death, γ ($0<\gamma<1$), is constant for individuals of all ages. Then the probability that an individual survives the next v periods is $(1-\gamma)^v$. The individual therefore discounts future consumption v periods ahead at the effective rate $\delta^v(1-\gamma)^v$. Applying this effective discount rate to equation (3.1) yields the certainty-equivalent utility function,

$$Ufl = \frac{1}{1-\theta} \sum_{v=t}^{\infty} (1-\gamma)^{v-t} \delta^{v-t} cfl_{a+v-t,v}^{1-\theta} \tag{3.2}$$

The effect of each of the discount factors, $(1-\gamma)$ and δ, is to tilt consumption towards the present period.

Since forward-looking individuals seek to maximize lifetime utility, it is appropriate to specify their budget constraint with a lifetime horizon. To accomplish this, define a present value factor α_t which is the inverse of single-period interest rates compounded

[28] More generally, $Cfl_{a+v-t,v}$ is the level of consumption in period v for an individual of age $a+v-t$. This reduces to $Cfl_{a,t}$ when v=t.
[29] The subjective discount factor δ, measures the marginal rate of substitution between consumption in two consecutive periods . In general, $\delta=1/(1+\rho)$, where ρ is the subjective marginal rate of time preference. In equilibrium, $\delta=1/(1+\rho)=1/(1+r)$, where $1/(1+r)$ is the market discount rate.
[30] The reciprocal of θ gives the elasticity of intertemporal substitution, σ; i.e. $\sigma=1/\theta$.

from period zero to period t-1:[31]

$$\alpha_t = \prod_{v=0}^{t-1} \left(\frac{1}{1+r_v}\right) \tag{3.3}$$

The discounted lifetime consumption for an individual of age a in period t is

$$\sum_{v=t}^{\infty} (1-\gamma)^{v-t} \alpha_{v-t} cfl_{a+v-t,v} \tag{3.4}$$

An individual's human wealth is lost when he dies; his financial asset, however, remains part of the wealth of the living. One way of motivating this property of financial assets is to assume that individual debtors purchase an insurance policy at the premium π to cover their debt, and individual savers receive a premium yield π on their financial assets each period they live.[32] In return for these premiums, the insurance agency assumes ownership of their debt or financial assets effective the period they die. With a large population, this contract ensures that the insurance agency collects with certainty, a fraction γ of every dollar of financial assets held in the economy.[33] Under perfect competition, equilibrium in the financial market requires that total dividend payments equals total collections plus accumulated interest, or $(1-\gamma)\pi = \gamma(1+r)$. This yields

$$\pi = \frac{\gamma(1+r)}{1-\gamma} \tag{3.5}$$

The total rate of return (*rc*) on individuals' financial assets is the sum of the market rate of return (*r*) and the *insurance* dividend, π. Individuals therefore discount future income at the effective rate *rc*,

$$rc = r + \pi \tag{3.6}$$

Applying equation (3.5) to equation (3.6) gives the effective discount factor 1+*rc*,

[31] This is the present value of a t-period annuity at a discount rate r_v, payable at the start of the year.
[32] π is proportional to an individual's financial assets.
[33] Although each individual is uncertain as to when he or she will die, the law of large numbers and the assumption that the young and the old are equally likely to die guarantee this result.

$$1+rc = \frac{1+r}{1-\gamma} \tag{3.7}$$

The human wealth in period t for a forward-looking individual can be written as the sum of discounted lifetime disposable labour income (*ydfl*),

$$hwfl_{a,t} = \sum_{v=t}^{\infty} (1-\gamma)^{v-t} \alpha_{v-t}\, ydfl_v \tag{3.8}$$

Forward-looking individuals hold financial assets that they accumulate through inheritance and from savings and debt commitments in the past. All financial assets accrue to forward-looking agents:

$$fa_{a,t} = \frac{1+r_{t-1}}{1-\gamma} fa_{a,t-1} \tag{3.9}$$

A forward-looking individual's total lifetime wealth (*twfl*) comprises of human wealth (*hwfl*) and financial assets (*fa*),

$$twfl_{a,t} = \sum_{v=t}^{\infty} (1-\gamma)^{v-t} \frac{\alpha_v}{\alpha_t} ydfl_v + \frac{1+r_{t-1}}{1-\gamma} fa_{a,t-1} \tag{3.10}$$

The forward-looking individual's lifetime budget constraint can then be written as

$$\sum_{v=t}^{\infty} (1-\gamma)^{v-t} \alpha_{v-t}\, cfl_{a+v-t,v} = twfl_{a,t} \tag{3.11}$$

The forward-looking consumer chooses the level of consumption for each period so as to maximize the certainty-equivalent utility (equation (3.2)) subject to the lifetime budget constraint (equation (3.11)). That is,

$$\max_{\{C_{a+v-t,v}\}} L = \frac{1}{1-\theta} \sum_{v=t}^{\infty} (1-\gamma)^{v} \delta^{v} cfl_{a+v-t,v}^{1-\theta} + \lambda [twfl_{a,t} - \sum_{v=t}^{\infty} (1-\gamma)^{v-t} \alpha_{v-t}\, cfl_{a+v-t,v}] \tag{3.12}$$

where λ is a lagrange multiplier representing the marginal utility of wealth. The first-order condition of utility maximization produces the results

$$\delta^{v-t}(1-\gamma)^{v-t} cfl^{-\theta}_{a+v-t,v} - \lambda(1-\gamma)^{v-t}\alpha_{v-t} = 0$$

which implies

$$cfl_{a+v-t,v} = \lambda^{-\frac{1}{\theta}}(\alpha_{v-t}\delta^{-(v-t)})^{-\frac{1}{\theta}} \tag{13}$$

The probability of death, γ, drops out of the first-order condition because it has identical influence on both the subjective discount factor and the market-effective present-value factor. Consequently, the marginal rate of substitution between the levels of consumption in any two consecutive periods is equal to the risk-free (market) discount factor $1/(1+r)$, which is independent of the probability of death. Thus, the discrepancy between the effective rate of interest applicable to individuals' decision making, rc, and the risk-free rate of interest applicable to society as a whole, r, does not distort intertemporal allocation of consumption.

Substituting equation (3.13) into the budget constraint (equation (3.11)) to derive an expression for λ, and then inserting λ back into equation (3.13) produce the exact form of the consumption function:

$$cfl_{a+v-t,v} = \Omega_t\left(\frac{\delta^{v-t}}{\alpha_{v-t}}\right)^{\sigma} twfl_{a,t} \tag{3.14}$$

where $\Omega_t = \{\sum_{v=t}^{\infty}[(1-\gamma)^{v-t}\frac{\alpha_v}{\alpha_t}]^{1-\sigma}[[(1-\gamma)\delta]^{v-t}]^{\sigma}\}^{-1}$

The term Ω_t represents the marginal propensity to consume out of wealth in period t. The marginal propensity to consume depends, in general, on the entire path of the effective rate of interest, but not on the age of the individual. This property reflects the assumption that the probability of survival $(1-\gamma)$ is independent of individuals' age, an assumption that facilitates aggregation of individual consumption functions into the aggregate consumption function.

3.2.2. *Aggregation Of Variables For Forward-Looking Agents*

We normalize population such that at birth each cohort consists of one individual. Given the probability of death (γ), the size of each cohort of age a is $(1-\gamma)^a$, and the size of the forward-looking agents population is

$$\sum_{a=0}^{\infty}(1-\gamma)^a = \frac{1}{\gamma} \tag{3.15}$$

The consumption of a forward-looking cohort of age a in period t is $(1-\gamma)^a Cfl_{a,t}$. Total consumption by forward-looking agents in period t is the total consumption of forward-looking individuals of all ages. Per capita total consumption by forward-looking agents is therefore given by

$$CFL_T = \gamma \sum_{a=0}^{\infty}(1-\gamma)^a cfl_{a,t} = \gamma \sum_{a=0}^{\infty}(1-\gamma)^a \Omega_t TWFL_{a,t} = \Omega_t TWFL_t \tag{3.16}$$

where

$$TWFL_t = HWFL_t + FA_t \tag{3.17}$$

$$FA_t = \gamma \sum_{a=0}^{\infty}(1-\gamma)^a ydfl_{a,t} - \gamma \sum_{a=0}^{\infty}(1-\gamma)^a cfl_{a,t} + \gamma \sum_{a=0}^{\infty}(1-\gamma)^{a-1}(1+r_{t-1}) fa_{a,t-1}$$

$$= YDFL_t - CFL_t + (1+r_{t-1}) FA_{t-1} \tag{3.18}$$

$$HWFL_t = \gamma \sum_{a=0}^{\infty}(1-\gamma)^a \sum_{v=t}^{\infty}(1-\gamma)^{v-t}\alpha_{v-t}\, ydfl_v = \sum_{v=t}^{\infty}(1-\gamma)^{v-t}\alpha_{v-t}\, ydfl_v \tag{3.19}$$

Manipulating the difference between equation (3.19) and its one-period lagged value gives

$$HWFL_t = \frac{1-\gamma}{1+r_t} HWFL_{t+1} + YDFL_t \tag{3.20}$$

TWFL, HWFL, FA and CFL represent per capita total wealth, human wealth, financial assets and consumption expenditures respectively for forward-looking individuals. Per capita aggregate consumption consists of per capita total consumption by forward-looking agents and per capita total consumption by *rule-of-thumb* agents. Based on the assumption that rule of thumb agents earn 40% of total disposable labour income (YD) with the remaining 60% accruing to *forward-looking* agents, per capita aggregate consumption expenditures (C_t) is determined by,

$$PC_t * C_t = \Psi * YD_t + \Omega_t TWFL_t + \Theta * (FA_t - FA_{ss}) \tag{3.21}$$

where *PC* is the relative price of consumption goods, *YD* is total disposable income, $\Psi * YD$ ($\Psi = 0.4$) is per capita total consumption by rule of thumb agents and $\Omega_t * TWFL$ is per capita total consumption by forward-looking agents. The steady-state value of financial assets (fa_{SS}) is exogenous to the *equilibrium* and *disequilibrium models*.[34] Therefore the last term, $\Theta*(Fa_t - Fa_{SS})$, is added to induce an extra wealth effect in a way that implicitly ties the (equilibrium) stock of financial assets to a terminal value. Moreover, per capita aggregate marginal propensity to consume is identical to the marginal propensity to consume by the individual consumer. This reflects the assumptions that individuals have identical utility functions, and individuals' spending propensities are independent of age.

[34] The *steady-state model* solves independently for the steady-state values of all endogenous variables in the model. The *equilibrium-* and *disequilibrium models* solve together to produce the equilibrium and disequilibrium (short-term) values for the endogenous variables.

Equation (3.17b), (3.18b), (3.20b) and (3.21b) are the versions used in the equilibrium model. That is, equation (3.17) solves for equilibrium total wealth for forward-looking agents (twfl.eq) which is the sum of equilibrium financial assets and equilibrium human asset for forward-looking agents. Equation (3.18) solves for equilibrium financial assets, equation (3.20) solves for equilibrium human wealth for forward-looking agents, and equation (3.21) solves for equilibrium consumption expenditures:

$$twfl.eq_t = hwfl.eq_t + fa.eq_t \tag{3.17b}$$

$$fa.eq_t = ydfl.eq_t - cfl.eq_t + (1 + r_{t-1})\, fa.eq_{t-1} \tag{3.18b}$$

$$hwfl.eq_t = \frac{1-\gamma}{1+r_t} hwfl.eq_{t+1} + ydfl.eq_t \tag{3.20b}$$

$$pc.eq_t * c.eq_t = \Psi * yd.eq_t + \Omega_t twfl.eq_t + \Theta * (fa.eq_t - fa_{ss}) \tag{3.21b}$$

$$pc_t * c_t = pc.eq_t * c.eq_t + cv1 * (yd_t - yd.eq_t) - cv2 * (rsl_t - rsl.eq_t)$$

$$* (1-\Psi) * pc.eq_t * c.eq_t + cv3 * (fa_t - fa.eq_t) - cadj_t + cshk_t \tag{3.22}$$

In equation (3.22), the disequilibrium consumption expenditures evolve as a function of its own equilibrium value and the deviation of disposable labour income, the slope of the yield curve and financial assets from their respective equilibrium values. The disequilibrium gap for disposable labour income (*yd - yd.eq*) reflects short-term fluctuations of the relative wage, employment and the income tax rate around their respective equilibrium values. The disequilibrium gap for the slope of the yield curve (*rsl - rsl.eq*) reflects effects of counter-cyclical monetary policy and short-term movements in domestic and international financial markets. The disequilibrium gap for financial assets (*fa-fa.eq*) reflects short-term fluctuations in the capital stock, the national debt-output ratio, and net foreign assets. Thus, the three terms allow short-term (disequilibrium) consumption expenditures to respond to cyclical dynamics in the economy. The fourth term (*cadj*) represents households' perceived costs of being away from the equilibrium rate of consumption and of adjusting towards this equilibrium.[35] The last term (*cshk*) is used to incorporate exogenous shocks to short-term households' consumption expenditures.

3.3. The Supply Side of the Model

Households own and supply labour and capital elastically to firms. Firms produce a single commodity using Cobb-Douglas production technology with constant returns to scale,

$$y.eq_t = \left(\frac{k.eq_{t-1}}{1+ydot}\right)^{\beta} \left(1-u.eq_t\right)^{1-\beta} \tag{3.23}$$

$$y_t = \left(\frac{k_{t-1}}{1+ydot}\right)^{\beta} \left(1-u_t\right)^{1-\beta} \tag{3.24}$$

where y, k, and $l=(1-u)$ are, respectively, real output, production capital and the part of the labour force currently employed.[36] β represents the elasticity of output with respect to capital, and ydot is the trend growth rate of real output.[37] The optimum levels of labour and capital, under perfectly competitive conditions, are determined by the respective marginal revenue products:

$$w.eq_t = (1-\alpha) * pfc.eq_t * \frac{y.eq_t}{1-u.eq_t} \tag{3.25}$$

$$w_t = w.eq_t - uv1 * (u_t - u.eq_t) + uv2 * (pfc_{t-1} - pfc.eq_{t-1})$$

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[35] Section 3.1 introduces these costs; chapter 4 discusses them in detail and derives the cost terms included in all behavioural equations in the model.

[36] The size of the labour force is normalized to unity; therefore, the employment rate is written as one minus the unemployment rate (i.e. l=1-u).

[37] The model uses a measurement convention that deflates all real variables by the trend growth rate of real output $(1+ydot)^t$ using 1986 as the base year. It also measures all prices relative to the domestic absorption deflator measured at factor cost (*pdfc*). *Pdfc* is exogenous to the model. In accumulation equations, lagged stock variables must be deflated accordingly to keep the units consistent. The measurement convention is fully discussed in chapter 4.

$$+uv3 * (tfp_{t-1} - tfp.eq_{t-1}) - wadj_t + wshk_t \tag{3.26}$$

$$k.eq_t = \frac{\alpha * pfc.eq_t * y.eq_t * (1+ydot)}{cc.eq_{t-1}} \tag{3.27}$$

$$cc.eq_t = \frac{[rk.eq_t + depr * (1 - tk.eq_t)] * pinv.eq_t}{1 - tk.eq_t} \tag{3.28}$$

$$k_t = k.eq_t + kv1 * (y_{t-1} - y.eq_{t-1}) - kv2 * (rsl_{t-1} - rsl.eq_{t-1}) * k.eq_{t-1} - kadj_t + kshk_t \tag{3.29}$$

where *cc.eq* is the equilibrium user cost of capital, *depr* is the rate of depreciation on capital, *pfc.eq* is the relative price of output at factor cost, *pinv.eq* is the equilibrium relative price of investment goods, *tk.eq* is the equilibrium tax rate on investment goods, and all other variables are as defined above. The rate of depreciation is exogenously set at 8 percent. The coefficient *kv1* incorporates the accelerator effect by linking the disequilibrium stock of capital with the output gap. The coefficient *kv2* transmits monetary policy shocks and other financial market shocks to the capital stock. Monetary policy affects the capital stock through changes in the level of investment expenditures as the slope of the yield curve fluctuates around its equilibrium level in response to monetary policy innovations.

The investment equation is written to reflect the fact that the flow of investment adjusts to meet and to maintain the desired stock of capital. This approach is consistent with the stock-flow relationships that are central to the structure of the model:

$$inv.eq_t = k.eq_t - (1 + depr)\, \frac{k.eq_{t-1}}{(1 + ydot)} \tag{3.30}$$

$$inv_t = k_t - (1 + depr)\, \frac{k_{t-1}}{(1 + ydot)} + ishk_t \tag{3.31}$$

where inv_t is net investment expenditures in period t.[38]

Total labour income (*ylab*) is the payments to labour based on the wage rate (*w*) and the level of employment (*1-u*),

$$ylab.eq_t = w.eq_t * (1 - u.eq_t) \quad (3.32)$$

$$ylab_t = w_t * (1 - u_t) \quad (3.33)$$

The equilibrium unemployment rate (*u.eq*) evolves as a function of its historical trend (*u.eqtrd*) and a three-year moving average of the equilibrium relative wage (*w.eq*). The historical trend is proxied by the Hodrick-Prescott trend of the historical data defined not to exceed 7.5 percent. The short-term (disequilibrium) unemployment rate reflects the equilibrium unemployment rate and the effect of cyclical factors proxied by the disequilibrium real output and relative wage gaps,

$$u.eq_t = Min(u.eqtrd_t, 0.075) + utrdw * \frac{1}{3}\sum_{t-2}^{0} w.eq_t \quad (3.34)$$

$$u_t = u.eq_t - uy1 * (y_t - y.eq_t) + uw1 * (w_t - w.eq_t) - uadj_t + ushk_t \quad (3.35)$$

Disposable income (*yd*) represents labour income minus net transfer to government. Net transfer to government is personal taxes less government transfer to households. Only a fraction (*tyd*) of government transfers to households is subject to taxes. *Tyd* is exogenously set at 0.5; personal income is taxed at the rate *td*.

$$yd.eq_t = (1 - td.eq_t) * (ylab.eq_t + tyd * gtr.eq_t) + (1 - tyd) * gtr.eq_t \quad (3.36)$$

[38] It is equally valid to think of this equation as determining the level of capital given the level of new investments, the rate of depreciation and the growth rate of the economy.

$$yd_t = (1 - td_t) * (ylab_t + tyd * gtr_t) + (1 - tyd) * gtr_t \tag{3.37}$$

3.4 The Government Sector

Fiscal policy in the model consists of choosing the desired national debt-output ratio (*gb*) using the personal income tax rate (*td*) as instrument. Subject to the target debt-output ratio, the government budget balances government outlays (including interest costs on the debt) with revenues (including new debt). Equation (3.38) and (3.39) represent the long-term and short-term fiscal policy reaction functions:

$$gb.eq_t = gb.eq_{t-1} - tdb1 * (gb.eq_t - gbtar) + tdm1 * dmgb.eq_t \tag{3.37}$$

$$pg.eq_t * g.eq_t + gtr.eq_t = td.eq_t * ylab.eq_t + tk.eq_t * prf.eq_t$$
$$+ tind.eq_t * pfc.eq_t * y.eq_t + gb.eq_t - \frac{(1+rgb.eq_{t-1})}{(1+ydot)} gb.eq_{t-1} \tag{3.38}$$

$$pg_t * g_t + gtr_t = td_t * ylab_t + tk_t * prf_t + tind_t * pfc_t * y_t + gb_t - \frac{(1+r_{t-1})}{(1+ydot)} gb_{t-1} \tag{3.39}$$

$$td_t = td.eq_t + td1 * (gb_t - gb.eq_t) \tag{3.40}$$

$$gtr_t = gtr.eq_t + gt1 * (y.eq_t - y_t) \tag{3.41}$$

where *prf* represents corporate profits before taxes, *tk* is the corporate income tax rate, *tind* represents indirect taxes, *gtr* is government transfer to households, *g* is government expenditures on goods and services, *pg* is the price of public goods and services, and *rgb* represents the interest rate on government debt. All other variables are as defined earlier.

Both *g.eq* and *g* are exogenous in the model. *Tk.eq, tk, tind.eq* and *tind* are also exogenous. The term *dmgb.eq* is a dummy variable that reflects the increase in the historical trend of the national debt-output ratio from the early 1980s to the mid-1990s. It takes on a value of zero for the period 1960-1982 and unity from 1983 to 1995. Equations (3.37-3.40) together solve for the values of *gb.eq, gb, td,eq* and *td*. Roughly, equation (3.37) determines *gb.eq*, equation (3.38) determines *td.eq*, equation (3.39) determines *gb*, and equation (3.40) determines *td*.

Household financial assets (*fa*) include claims to physical capital (*k*), government bonds (*gb*), and foreign bonds (*nfa*).[39] These stock variables relate to each other through the equilibrium and disequilibrium stock identities,

$$fa.eq_t = pk.eq_t * k.eq_t + gb.eq_t + nfa.eq_t \tag{3.42}$$

$$fa_t = pk_t * k_t + gb_t + nfa_t \tag{3.43}$$

Businesses determine the levels of *k.eq* and *k*, and the fiscal authority determines *gb.eq* and *gb*. Households choose the desired levels of *fa.eq* and *fa*; therefore, *nfa.eq* and *nfa* evolve as residuals in the stock identities (equations (3.42 and 3.43)) to support households' choice of *fa.eq* and *fa*. The equilibrium level of net foreign assets (*nfa.eq*), in turn, corroborates with equilibrium net exports (*netx.eq*) to determine the equilibrium real exchange rate (*z.eq*).[40] In effect, the equilibrium stock identity (equation (3.42)) is normalized on the equilibrium real exchange rate.[41]

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[39] The sign convention defines assets from the perspective of the consumer. Thus, while *gb* represents government liability, it enters equations 3.42 and 3.43 with a positive sign. On the other hand, *nfa* enters the equations with a negative sign on account that there in net foreign debt.

[40] The equilibrium net foreign assets and equilibrium net exports approximately determine the underlying long-term balance of payments; hence they must determine the equilibrium real exchange rate.

[41] Thus, equation (3.18b) actually determines *fa.eq* while equation (3.42) determines *z.eq*. The model does not include an independent equation for *z.eq*. However, it includes an independent equation for the disequilibrium real exchange rate to reflect the relatively complex factors that account for short-term real exchange rate movements.

3.5 The Foreign Sector

The foreign sector features stock-flow dynamics that support the underlying balance of payments. Net foreign assets accumulate from net exports and interest payments on previous stocks of foreign assets,

$$nfa.eq_t = \frac{1+rnfa.eq_{t-1}}{1+ydot} nfa.eq_{t-1} + netx.eq_t \tag{3.44}$$

$$nfa_t = \frac{1+rnfa_{t-1}}{1+ydot} nfa_{t-1} + netx_t \tag{3.45}$$

$$netx.eq_t = px.eq_t * x.eq_t - pm.eq_t * m.eq_t \tag{3.46}$$

$$netx_t = px_t * x_t - pm_t * m_t \tag{3.47}$$

where *rnfa* is the real return on net foreign assets, *x* and *m* are real exports and real imports respectively, and *px* and *pm* are, respectively, the relative prices of exports and imports in domestic currency. As section 3.4 shows, equation (3.44) and (3.45) combine with equation (3.42) to determine the equilibrium real exchange rate. The short-term (disequilibrium) real exchange rate (*z*) is determined by a version of the nominal interest parity condition modified to include inertia from its own lagged value and from the equilibrium exchange rate. An increase (depreciation) of the equilibrium real exchange rate (z.eq) causes real short-term depreciation in the real exchange rate. Similarly, a decline in real short-term interest rates relative to the equilibrium short-term rate (r.eq) depreciates the short-term real exchange rate.

The expected real exchange rate (*ze*) evolves as a function of the one-year model-consistent forecasts for the equilibrium and diseqilibrium real exchange rates, and the one-year lagged value of the disequilibrium real exchange rate,

$$z_t = z1 * z_{t-1} + z2 * ze_t * \frac{1 + r.eq_t}{1 + r_t} + (1 - z1 - z2) * z.eq_t + zshk_t \tag{3.48}$$

$$ze_t = zf1 * z_{t+1} + zl1 * z_{t-1} + (1 - zf1 - zl1) * z.eq_{t+1} + zshk_t \tag{3.49}$$

where *r.eq* and *r* are the equilibrium and disequilibrium short-term interest rates, and zshk is the shock term that allows the actual real exchange rate to be exogenously shocked. *R.eq* is exogenously set to the equilibrium short-term interest rate in international financial markets (proxied by the 90-day U.S money market funds rate). Thus, agents form expectations about the short-term real exchange rate by a process that is partly rational and partly adaptive.

The equilibrium ratio of imports to total output is proportional to the level of domestic absorption.[42] The coefficient of proportionality (*mpr.eq*) depends on the historical import-penetration ratio (*mpr0,*) and on the ratio of the relative equilibrium price of imports (pm.eq) to the relative equilibrium price of output at factor cost (pfc.eq). *Mpr0* is exogenous, and *pm.eq* is expressed in domestic currency. The short-term (disequilibrium) import-penetration ratio (*mpr*) reflects the equilibrium import-penetration ratio adjusted for the disequilibrium gap of the relative price of imports (*pm/pfc-pm.eq/pfc.eq*),

$$pm.eq_t * m.eq_t = mpr.eq_t * (pc.eq_t * c.eq_t + pk.eq_t * inv.eq_t + pg.eq_t * g.eq_t + px.eq_t * x.eq_t) \tag{3.50}$$

$$pm_t * m_t = mpr_t * (pc_t * c_t + pk_t * inv_t + pg_t * g_t + px_t * x_t) \tag{3.51}$$

$$mpr.eq_t = mpr0_t - mpr1 \frac{pm.eq_t}{pfc.eq_t} \tag{3.52}$$

[42] This specification presumes that exports have the same import-content as non-traded goods.

$$mpr_t = mpr.eq_t - mpr2\left(\frac{pm_t}{pfc_t} - \frac{pm.eq_t}{pfc.eq_t}\right) - mpradj_t \tag{3.53}$$

In equation (3.53), *mpradj* reflects slow adjustments of the import-penetration ratio resulting from costs to businesses for not achieving the equilibrium import-output ratio, and the costs of adjusting to that equilibrium. Section 3.1 briefly describes the exact nature of these costs; chapter 4 discusses them in detail.

The equilibrium ratio of exports to total output depends on the historical exports-to-output ratio (*calx1*) and on the equilibrium relative price of exports (*px.eq*) expressed in domestic currency units. *Px.eq* depends positively on the relative price of imports in the rest of the world (*pmrow*) and on the equilibrium real exchange rate. The relative price of U.S imports proxies for *pmrow*, and the Canada-U.S real exchange rate proxies *z.eq*. In the short-run, the ratio of exports to output (*z*) depends on the underlying equilibrium ratio (*z.eq*) and on (lagged) fluctuations of the relative price of exports and the real exchange rate around their respective equilibrium levels;

$$x.eq_t = calx1 + xx2 * px.eq_t \tag{3.54}$$

$$x_t = x.eq_t + xv1*\left(px_{t-1} - px.eq_{t-1}\right)*x.eq_t + xv2*\left(z_{t-1} - z.eq_{t-1}\right)*x.eq_t - xadj_t \tag{3.55}$$

The term *xadj* reflects sluggish adjustment of the export-output ratio resulting from costs to businesses for not achieving the equilibrium rate of exports, and the costs of adjusting to the equilibrium rate.

3.6 Relative Prices

As mentioned elsewhere in this chapter, the model expresses each price as a ratio to the domestic absorption deflator at factor cost, *pdfc.eq*. Thus, all prices in the model measure relative prices. *Pdfc.eq* is exogenous. Chapter 4 discusses this measurement convention in detail.

3.6.1 Relative Prices in the Traded Sector

The equilibrium relative price of imports (*pm.eq*) evolves as a function of its own lagged value, the relative price of exports in the rest of the world (*pxrow*), and the equilibrium real exchange rate, *zeq*. The relative price of U.S. exports in domestic currency proxies for *pxrow*. The short-term (disequilibrium) relative price of imports depends on the underlying equilibrium relative price of imports (*pm.eq*), fluctuations in the real exchange rate around its equilibrium level, and changes in the relative price of exports abroad ($pxrow_t$-$pxrow_{t-1}$). The model assumes that imports are not subject to tarrifs;

$$pm.eq_t = pme1 * pm.eq_{t-1} + pme2 * pxrow_t * z.eq_t \tag{3.56}$$

$$pm_t = pm.eq_t + pm2 * (z_t - z.eq_t) * pxrow_t + pm3 * (pxrow_t - pxrow_{t-1}) * z.eq_t - pmadj_t \tag{3.57}$$

As usual, the term *pmadj* reflects slow adjustments in the relative price of imports arising from costs to businesses for not achieving the equilibrium rate of imports, and the costs of adjusting to the equilibrium rate.

The equilibrium relative price of exports (*px.eq*) evolves as a function of its own lagged value, the relative price of imports in the rest of the world (*pmrow*) and the equilibrium real exchange rate (*z.eq*). The ratio of U.S import price index to the U.S. GDP deflator at factor cost proxies for *pmrow*; the Canada-U.S real exchange rate proxies for (*z.eq*). The short-term (disequilibrium) relative price of exports (*px*) depends on the underlying equilibrium relative price of exports, the fluctuations in the real exchange rate around its equilibrium level, and changes in the relative price of foreign exports. The model assumes that exports are not subject to tarrifs;

$$px.eq_t = pxe1 \bullet px.eq_{t-1} + pxe2 \bullet pmrow_t \bullet z.eq_t \tag{3.58}$$

$$px_t = px.eq_t + px3 * pmrow_t * (z_t - z.eq_t) + px5 * (pmrow_t - pmrow_{t-1}) - pxadj_t \tag{3.59}$$

The term *pxadj* reflects slow adjustments in the relative price of exports arising from costs to businesses for not achieving the equilibrium rate of exports, and the costs of adjusting to that equilibrium.

3.6.2 Relative Prices in the Non-traded Sector

The non-traded sector features three relative prices according to the major components of domestic absorption: the relative price of consumer goods (*pc*), the relative price of investment goods (*pinv*), and the relative price of public goods (*pg*). Each relative price depends on a sector-specific index of domestic factor cost (*pfci*, i = *c*, *inv*, and *g*), the import-content of the sector's output (*imeq*, i = *c*, *inv*, and *g*), the price of imported goods (*pm*), and the sector-specific effective indirect tax rate (*ti*, i = *c*, *inv*, and *g*).[43] This structure makes the relative prices sensitive to conditions in domestic factor markets, competitive pressure from imported substitutes, and movements in prices of imported inputs. The three relative prices differ for a number of reasons. First, each sector's product may be subject to different effective indirect tax rates (*ti*, i = *c*, *inv*, and *g*). Second, each sector may experience a different form and intensity of international competition, demand and supply shocks, and technological growth.[44] Finally, prices of imports, including movements in the exchange rate, will have different effects on each sector if import-contents vary across sectors. Equation (3.60) specifies the general form of the three relative prices in the equilibrium model; equation (3.61) specifies their counterparts in the short-term (disequilibrium) model:

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[43]Each sector's *import content* is proxied by the ratio of its imports to its total value added averaged over 1965-95.

[44] For example, historical differences in the growth of relative prices for consumption goods and for investment goods (especially computers and related equipment's) cannot be explained solely on the basis of differences in indirect taxes.

$$pi.eq_t * i.eq_t = \left(\left(1 - imeq\right) * pfci.eq_t + imeq * pmeq_t\right) * i.eq_t + \frac{ti_t}{\left(1 + ti_t\right)} pi.eq_t * i.eq_t \quad (3.60)$$

$$pi_t * i_t = \left(\left(1 - imeq\right) * pfci_t + imeq * pm_t\right) * i_t + \frac{ti_t}{\left(1 + ti_t\right)} pi_t * i_t \quad (3.61)$$

where $i = c$, *inv* and *g* represent consumption goods, investment goods, and public goods respectively, and all other variables are as defined earlier.

The equilibrium sector-specific index of domestic factor cost (*pfci.eq*, $i = c$, *inv*, and *g*) are exogenously set to the historical data implicit in equation (3.60). Their disequilibrium counterparts (*pfci*, $i = c$, *inv*, and *g*) are endogenous;

$$pfcc_t = pfcc.eq_t + pck1 * Max\left(ygap_t, 0\right) + pck2 * ygap_t + pk3 * pmgap_t \quad (3.62)$$

$$pfcinv_t = pfcinv.eq_t + pkk_1 * pmgap_t + pkk_2 * zgap_t * prow_t + pkk_3 * invgap_t \quad (3.63)$$

$$pfcg_t = pfcg.eq_t + pgk1 * pkgap_t + pgk2 * pmgap_t + pgk3 * wgap_t \quad (3.64)$$

where *pmgap* refers to *pm-pm.eq*, *zgap* refers to *z-z.eq*, *invgap* refers to *inv-inv.eq*, *pkgap* refers to *pk-pk.eq*, *wgap=w-w.eq*, *ygap=y-y.eq*, and all other variables are as defined earlier. The term Max(ygap, 0) allows equation (3.62) to select, in each period, the maximum of the two values *ygap* and zero (i.e. *ygap* if *ygap*>0, or 0 if *ygap*<0. An identity that reflects nominal output at factor cost (equation (3.65)) reconciles the sector-specific domestic relative prices. Moreover, the aggregate demand identities (in nominal and real terms) reconcile the relative prices with the rest of the model:

$$pfc.eq_t * y.eq_t = \sum_i \left(\left(1 - imeq\right) * pfci_t + imeq * pm.eq_t\right) * i.eq_t \quad (3.65)$$

$$py_t * y_t = pfc_t * y_t + \sum_i \frac{ti_t}{1 + ti_t} pi_t * i_t \quad (3.66)$$

$$py.eq_t * y.eq_t = pc.eq_t * c.eq_t + pinv.eq_t * inv.eq_t + pg.eq_t * g.eq_t + px.eq_t * x.eq_t - pm.eq_t * m.eq_t \quad (3.67)$$

$$py_t * y_t = pc_t * c_t + pinv_t * inv_t + pg_t * g_t + px_t * x_t - pm_t * m_t \quad (3.68)$$

$$y.eq_t = c.eq_t + inv.eq_t + g.eq_t + x.eq_t - m.eq_t \quad (3.69)$$

$$y_t = c_t + inv_t + g_t + x_t - m_t \quad (3.70)$$

where $i = c$, *inv*, and g in equations (3.65) and (3.66), and all other variables are as defined earlier.

3.7 The Phillips Curve: Determinants of Inflation and Inflation Expectations

3.7.1 Determinants of Inflation

The Phillips curve determines trend inflation (*pdot*), in the model. The trend inflation (pdot) estimates inflation in the domestic absorption deflator at factor cost (pdfc), which is the numeraire price in the model. The Philips curve equation (3.71) incorporates both short-term non-neutrality and long-term neutrality. In the short-run, the rate of inflation depends positively on the current and one-period lagged values of excess demand.[45] Moreover, the short-run output-inflation trade-off reflects asymmetries that cause positive excess demand to raise inflation more strongly than an equivalent excess supply lowers it.[46] In the medium- to long-run, the output-inflation trade-off disappears, leaving the trend inflation to evolve as a function of expectational dynamics and relative price movements between the traded and non-traded sectors of the economy;

$$pdot_t = pfd1_t\left(pdl1 * pdote_t (1 - pdl1) * pcdote_t\right)$$
$$+ pfd2 * \left(pdv1 * pdot_{t-1} + pdv2 * pdot_{t+1} + \left(1 - pdv1 - pdv2\right) * pcdot_{t-1}\right)$$

[45] The model uses the excess of short-term (disequilibrium) real output over the equilibrium real output (*y-y.eq*) as proxy for excess demand.

[46] See Laxton, Rose, and Tetlow (1993) and Debelle and Laxton (1996).

$$+pydl*(y_{t-1}-y.eq_{t-1})+pyd*(y_t-y.eq_t)+ped*Max(y_t-y.eq_t,0)$$

$$+pdm1*\left(\frac{pm_t}{pm_{t-1}}-1\right)+pdx1*\left(\frac{px_t}{px_{t-1}}-1\right)+wdk1*\left(\frac{w_t}{w_{t-1}}-1\right) \qquad (3.71)$$

where *pfd1, pdl1, pd, pdv1, pdv2, pydl, pyd, ped, pdm1, pdx1* and *wdk1* are parameters. The term Max(y_t-y.eq_t, 0) embodies the short-term asymmetric effect of excess demand and excess supply.[47] The terms *pdote* and *pcdote* represent agents' expectations about *trend inflation* and inflation in the *consumer price index* respectively. Agents form inflation expectations by a process that is partly adaptive and partly rational. Equations (3.73) and (3.74) specify the processes that determine *pdote* and *pcdote*. The terms that represent growth in the relative price of imports (*pm*) and in the relative price of exports (*px*) reflect inflation in import and export prices relative to inflation in the numeraire price. These terms allow foreign shocks (for example terms of trade shocks) to *pass through* into domestic costs and prices. They also reflect the effects of relative price movements between the traded sector and the non-traded sector, and therefore the impact foreign competition makes on domestic prices. Finally, the growth rate in the relative wage (w) reflects how labour costs impact on the overall trend inflation in the economy.

Inflation in the consumer price index depends on the trend inflation (*pdot*) and the difference between growth rates in the relative price of output at market prices (*py*) and the relative price of output at factor cost (*pfc*);

$$pcdot_t = pdot_t + \left(\frac{py_t}{py_{t-1}}-1\right) - \left(\frac{pfc_t}{pfc_{t-1}}-1\right) \qquad (3.72)$$

Since all indirect taxes in the model are exogenous, the difference between pdot and pcdot reflects the effects of indirect taxes and subsidies in the historical data.

[47] In the case of excess demand (y_t-$y.eq_t$>0) this term raises pdot; in the case of excess supply (y_t-$y.eq_t$<0)

3.7.2 How Agents Form Inflation Expectations

Although agents are forward looking with regard to forming expectations about inflation, they also rely on past experience as well as their perception of the monetary authority's inflation target. That is, inflation expectations are partly rational and partly adaptive. Households and businesses both form expectations about inflation in the price of consumption goods (*pcdote*). Businesses also form expectations about trend inflation (*pdote*) which indicates the path of underlying production costs in the future. The model assumes that both *pcdote* and *pdote* evolve by a similar process;

$$pdote_t = pde1 * pdote_{t-1} + pde2 * pdot_{t+1}$$

$$+ pde0 * ((pdot_{t+2} + pdot_{t+3})/2) + pde0 * pdottar_t \qquad (3.73)$$

$$pcdote_t = pcde1 * pcdote_{t-1} + pcde2 * pcdot_{t+1}$$

$$+ pcde3 * ((pdot_{t+2} + pdot_{t+3})/2) + pcde0 * pdottar_t \qquad (3.74)$$

where *pde1*, *pde2*, *pde3*, *pcde1*, *pcde2* and *pcde3* are parameters, and *pdottar* is the monetary authority's inflation target. Thus, agents expect each year's inflation to evolve as a function of inflation forecast in the previous year, the model-consistent inflation rates one-year to three years ahead, and the monetary authority's inflation target for the year. As noted elsewhere in this section, these inflation expectation rules reflect a notional wage bargaining paradigm where agents consider intertemporal and sectoral distribution of the relative wage when they bargain for new contracts.[48] The extent of monetary policy credibility in the model depends on the weight the expectation process assigns to the monetary authority's inflation target (*pdottar*). The simulation exercises in chapters 4, 5 and 6 assign a weight of approximately 20 percent to *pdottar*. [49]

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the term defaults to zero and does not contribute anything to pdot.

[48] See Fuhrer and Moore (1995a; 1995b), Buiter and Miller (1985), and Taylor (1980)..

[49] The small weight on the inflation target most likely understates actual credibility of monetary policy. However, as chapter 2 explains, it reflects the fact that the thesis focuses more on costs than on benefits of

3.8 Monetary Policy

Historically, Canadian monetary policy has focused on a variety of targets at different times. The well-documented targets include chartered banks reserves (between 1965 and 1975); money supply (M1) growth (between 1975 and 1978); the exchange rate and money supply growth (between 1978 and 1984, and money supply growth until 1988); and the rate of inflation since 1989. However, analysts hold that the Bank of Canada's operating procedures with regard to monetary policy have remained fairly stable across all the policy regimes. [50] The operating procedure has, more or less, involved daily injection of cash into the economy, or withdrawal of cash from the economy, by transferring federal government demand deposits between the government's accounts at the central bank and its accounts at the chartered banks. This procedure has almost invariably made the Bank of Canada's funds rate, and hence the short-term lending rate, an important instrument (and sometimes an intermediate target) in the implementation of monetary policy.

Besides monetary policy innovations, other factors such as developments in international financial markets and changes in inflationary expectations affect interest rates. As a result, it is often difficult to evaluate monetary policy stance based on the level of interest rates. On the other hand, monetary policy tends to have greater influence on short-term rates than on long-term rates, and therefore causes predictable movements in the slope of the yield curve. Thus, the slope of the yield curve provides a more reliable measure of monetary policy stance than does any measure of interest rates.[51] Consequently, the model specifies the monetary policy reaction function in terms of the slope of the yield curve (*rsl*), which measures the difference between short-term nominal interest rate *rn* and the long-term nominal interest rate *rnl*. The model proxies short-term rates by the 90-day

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inflation reduction. The inflation expectation process in CPAM assigns a 10 percent weight to the expected inflation target.

[50] See Howitt W. Peter (1993, 472) ; Clinton, Kevin(1991, pp 3-25) ; and Bank of Canada Review (June 1975, 3-12).

[51] See Cote, and Macklem(1996) and Macklem, Paquet and Phaneuf(1996).

treasure bill rate, and long-term nominal interest rates by the 10-year government of Canada bond rate.

Monetary policy consists of using the slope of the yield curve (*rsl*) as instrument to target the desired level of inflation in the consumer price index;

$$rsl_t = rsl.eq_t + rsl2 * (pcdote_{t+2} - pdottar_t) + rslshk_t \tag{3.75}$$

$$1 + rsl.eq_t = \frac{1 + rn.eq_t}{1 + rnl.eq_t} \tag{3.76}$$

where *rsl.eq* is the equilibrium slope of the yield curve, *rsl* is the short-term (disequilibrium) slope of the yield curve, *rn.eq* and *rnl.eq* are the short-term and long-term equilibrium nominal interest rates respectively, and *rsl1* is a parameter. The term *rslshk* provides an avenue to introduce exogenous shocks to the slope of the yield curve. All other variables are as defined earlier. According to the monetary policy reaction function (equation (3.75), the monetary authority responds to the two-year ahead forecast inflation gap ($pcdote_{t+2} - pdottar_t$) by moving its fundamental instruments to adjust the short-term (disequilibrium) slope of the yield curve (rsl).

Monetary policy has countercyclical effect in the *short-term (disequilibrium) model.* When an anticipated inflationary shock raises the two-year forecast inflation in the consumer price index and creates a positive forecast inflation gap, monetary policy tightens as the monetary authority raises the slope of the yield curve according to the monetary policy reaction function (equation (3.75)). Since the monetary authority conventionally operates on the shorter end of the market, the policy initially raises short-term rates relative to long-term rates, thereby causing the slope of the yield curve to rise. Eventually, long-term interest rates also rise, increasing the costs of borrowing further and reducing investment expenditures and interest-sensitive consumption expenditures.

The risk premium built into long-term (equilibrium) interest rates provide avenue for monetary policy to exert long-term effect in the model. The equilibrium risk premium depends positively on *excess inflation* (defined as the rate of inflation in the consumer price index in excess of 3 percent).[52] In periods of high inflation, the higher equilibrium risk premium associated with the positive *excess inflation* raises equilibrium long-term interest rates and the equilibrium user cost of capital and thereby reduce long-term (equilibrium) investment expenditures and consumption expenditures. Low inflation rates produce the opposite effect, ultimately raising long-term investments and consumption expenditures. Section 3.9 contains the nexus of interest rates that support these short-term and long-term dynamics in the model's financial sector.

3.9 The Term Structure of Interest Rates

The model ties the equilibrium short-term real interest rate (*r.eq*) to the US short-term interest rate (*rus.eq*) based on the small open-economy assumption.[53] Therefore, *r.eq* is exogenous. The Fisher equation determines the equilibrium short-term nominal interest rate (*rn.eq*) based on *r.eq* and the trend inflation rate (*pdot*). In the short-term (*disequilibrium*) model, an equation for the slope of the yield curve determines real and nominal short-term interest rates, *r* and *rn* respectively. This structure links the disequilibrium short-term interest rates directly to the effect of monetary policy, and thereby provides avenue for onward transmission of monetary policy innovations to the rest of the model;

$$r.eq_t = usr.eq_t \tag{3.77}$$

$$1+rn.eq_t = (1+r.eq_t)*(1+pdot_t) \tag{3.78}$$

[52] The 3 percent threshold is arbitrary. However, the monetary policy debate in the 1990s indicates that inflation expectations on the opposite sides of the 2%-4% inflation range could be quite different.

$$1+r_t=(1+rl_t)*(1+rsl_t) \quad (3.79)$$

$$1+rn_t=(1+rnl_t)*(1+rsl_t) \quad (3.80)$$

Real and nominal long-term equilibrium rates (*rl.eq* and *rnl.eq* respectively) evolve as functions of their respective short-term rates (*r.eq* and *rn.eq* respectively) and an equilibrium risk premium (rt.eq) that depends positively on *excess inflation*. Excess inflation measures the rate of inflation in the consumer price index in excess of 3 percent[54] The nominal long-term interest rate (*rnl*) in the short-term (disequilirium) model, evolves as a function of the equilibrium risk premium (*rt.eq*) and a geometric mean of the equilibrium and disequilibrium short-term rates. The Fischer equation determines the real long-term rate (*rl*) based on the trend inflation (*pdot*). This structure enables the disequilibrium long-term rates to respond to current market conditions and simultaneously respect the underlying equilibrium based on fundamentals;

$$1+rl.eq_t=(1+r.eq_t)*(1+rt.eq_t) \quad (3.81)$$

$$1+rnl.eq_t=(1+rn.eq_t)*(1+rt.eq_t) \quad (3.82)$$

$$rt.eq_t=rt0*(1+rtp1*(pdot_t-0.03)) \quad (3.83)$$

$$1+rl_t=\frac{1+rnl_t}{1+pcdot_{t+1}} \quad (3.84)$$

$$1+rnl_t=(1+rt.eq_t)*((1+rn_t)*(1+rn.eq_t))^{\frac{1}{2}} \quad (3.85)$$

where *rt0* and *rtp1* are parameters.

The model defines the net return on capital (*rk.eq*), the return on foreign assets (*rnfa.eq*),

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[53] Rus.eq is proxied by the three-month US commercial paper rate.

[54] As section 3.7 explains, although the 3 percent threshold is arbitrary, it, nevertheless, fits the range of

and the return on government debt (*rgb.eq*) as the sum of the risk-free real long-term rate (rl.eq) and an instrument-specific risk premium (*rkp.eq*, *rnfp.eq* and *rgb.eq* respectively);

$$rk.eq = rl.eq_t * \left(1 + \frac{1 + rsl.eq_t}{1 + rt.eq_t}\right) + rkp.eq_t \quad (3.86)$$

$$rnfa.eq = rnfap.eq_t + rl.eq_t \quad (3.87)$$

$$rnfa = rnfap.eq_t + rl_t \quad (3.88)$$

$$rgb.eq = rgbp.eq_t + rl.eq_t \quad (3.89)$$

$$rgb = rgbp.eq_t + rl_t \quad (3.90)$$

All the risk premiums are exogenous; rkp.eq was endogenized in calibrating the model;

3.10 Adjustments Terms In The Short-Run Disequilibrium Model

Chapter 3 discusses the three levels of structural relationships in the model, and shows that this stratification creates three distinct sub-models: the *steady-state model*, the *equilibrium model* and the *short-term (disequilibrium) model*. The steady-state model represents long-run equilibrium relationships that abstract from all forms of dynamic adjustments. The *equilibrium model* represents medium-term structural relationships including limited dynamics that reflect intrinsic stock-flow relationships in the economy.

The disequilibrium model adds four types of adjustments to those present in the equilibrium model. The first type of adjustment reflect the gradual nature of agents' responses to shocks due to rigidities arising from such constraints as irreversibility of certain investment decisions and past contracts still in effect. The second type of adjustment reflects the fact that agents' expectations are partly adaptive. Agents update

values suggested by the current monetary policy debate in Canada.

their perception of the future and adjust their behaviour accordingly as they obtain more information. The third type of adjustment arises from endogenous reaction of monetary and fiscal policies to cyclical movements in the economy. The disequilibrium model also includes shock terms in all behavioural equations. These shock terms provide avenue to introduce exogenous shocks to the model.

The first type of disequilibrium adjustment receives the most elaborate treatment in the model. Agents choose the adjustment path of each choice variable to minimize two types of costs: the expected cost of being away from equilibrium, and the expected cost of adjusting towards equilibrium.[55] For a typical flow variable (y), this involves choosing the adjustment path y_{t+i} for all periods $i \geq 0$ to minimize the quadratic approximation of adjustment costs that penalize one-period to k-period changes in y,

$$C_1 = E_t\left\{\sum_{i=0}^{\infty}\beta^i\left[b_0\left(y_{t+i} - y^*_{t+i}\right)^2 + \sum_{k=1}^{m}\phi_k\left(\left(1-L^k\right)y_{t+i}\right)^2\right]\right\} \tag{3.91}$$

where β is the rate at which agents discount future adjustment costs, L is the lag operator and the sequence of parameters ϕ_k reflect the speed of adjustment. This disequilibrium adjustment structure can closely represent the effect of seasonal or multi-period contracts.[56] The first term in equation (3.91) represents the (static) cost of being away from the equilibrium value y^* in period $t+i$, the second term represents the (dynamic) costs of k-periods adjustment in y.

For a typical stock variable y, agents choose an adjustment path to minimize the quadratic approximation of adjustment costs that penalize changes in the level, in growth rate or in any kth-order difference of y;

$$C_2 = E_t\left\{\sum_{i=0}^{\infty}\beta^i\left[b_0\left(y_{t+1} - y^*_{t+1}\right)^2 + \sum_{k=1}^{m}\phi_k\left(\left(1-L\right)^k y_{t+i}\right)^2\right]\right\} \tag{3.92}$$

[55]See Black and Rose(1996).

As in equation (3.91), the first term in equation (3.92) represents the (static) cost of being away from the equilibrium value y^* in period $t+i$. The second term penalizes changes in the level of y when $k=1$; it penalizes changes in the growth rate of y when $k=2$; etc.

The model restricts the value of m to 2 so that k takes on the values 1 and 2 in equations (3.91) and (3.92). Thus, in the case of flow variables, the second term in equation (3.91) includes only one- and two-period changes in the level of y. In the case of stock variables, the second term in equation (3.92) includes only changes in the level and in the growth rate of y.

The first-order condition for the minimization of equations (3.91) and (3.92) yields, respectively,

$$y_t = y_t^* + yadj_t \tag{3.93}$$

where

$$yadj_t = -\phi_1(y_t - y_{t-1}) + \beta\phi_1(y_{t+1} - y_t) - \phi_2(y_t - y_{t-2}) + \beta^2\phi_2(y_{t+2} - y_t)$$

when y is a flow variable, and

$$yadj_t = -\phi_1(y_t - y_{t-1}) + \beta\phi_1(y_{t+1} - y_t) - \phi_2(y_t - 2y_{t-1} + y_{t-2}) \\ + 2\beta\,\phi_2(y_{t+1} - 2y_t + y_{t-1}) - \beta^2\phi_2(y_{t+2} - 2y_{t+1} + y_t)$$

when y is a stock variable. All variables are as defined earlier. The behavioural equations in the short-term disequilibrium model take the form of equation (3.93). They also include additional terms based on structural relationships in the model. To illustrate with a typical stock variable, the equation that determines the capital-output ratio (k) in the disequilibrium model is,

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[56] See Tinsley, P. A. (1993).

$$k_t = k_t^* - kv1\,(y_{t-1} - y_{t-1}^*) + kv2\,(rsl_{t-1} - rsl_{t-1}^*)\,k_{t-1}^* - kadj_t + kshk_t \qquad (3.94)$$

where y is real output, and

$$kadj_t = \phi_1(k_t - k_{t-1}) - \beta\phi_1(k_{t+1} - k_t) + \phi_2(k_t - 2k_{t-1} + k_{t-2})$$
$$-2\beta\,\phi_2(k_{t+1} - 2k_t + k_{t-1}) + \beta^2\phi_2(k_{t+2} - 2k_{t+1} - k_t)$$

Equation (3.94) differs from equation (3.93) by the two terms with coefficients *kv1* and *kv2* and the term *kshk*. The terms with coefficients *kv1* and *kv2* are based on structural relationships in the model. They provide an avenue for the propagation of cyclical effects as the economy adjusts to various kinds of shocks. The coefficient *kv1* incorporates the accelerator effect by linking the disequilibrium stock of capital with the lagged output gap. The coefficient *kv2* transmits monetary policy shocks and other financial market shocks to the capital-output ratio. Chapter 3 discusses these structural relationships in detail. The term *kshk* provides an avenue for introducing exogenous shocks to the capital-output ratio, and *kadj* is the adjustment term derived in equation (3.93). The discount factor (β), and the coefficients (ϕ_1 and ϕ_2) which determine the speed of adjustment are calibrated to improve the fit of the model.

This chapter has described the structure of the model in detail. This is the baseline model. It does not, as yet, incorporate the downward nominal wage rigidity assumption (to be introduced in chapter 6). The next chapter (chapter 4) calibrates the model. The chapter begins with a discussion of the calibration methodology, highlighting key aspects of the calibration technique including some well-known advantages and disadvantages relative to conventional estimation methods. The chapter also discusses measurement conventions used in the model, and derives the structural shocks required to perform stochastic simulations in chapters 5 and 6.

CHAPTER 4

CALIBRATION OF THE MODEL

This chapter explains how the model was calibrated. It contains 5 major sections. Section 4.1 discusses the calibration methodology and some practical issues that arise from applying the technique to macroeconomic models. Section 4.2 explains how the model normalizes variables and the corresponding time series data. Section 4.3 produces diagnostic simulation results to illustrate how the calibrated model fits the historical data. Finally, section 4.4 derives structural shocks for stochastic simulation in chapters 5 and 6.

4.1 The Calibration Methodology: Techniques, Advantages, and Limitations

A model is calibrated when its parameters are chosen from prior econometric studies and other sources that provide information about the structure of the economy being modeled. The calibration process involves choosing the parameters for the model, simulating the model to compare selected characteristics of the simulated output with analogous features of the actual data and, if necessary, re-examining relevant aspects of the theory and/or the parameters based on those comparisons. The metric frequently used to compare model output with the actual data include variances and covariances of key model variables, impulse responses by key variables to deterministic shocks, durations, spectra analysis and Euler equations.[57] Manuelli and Sargent (1988), Gregory and Smith (1990), and Canova (1991) interpret calibration as a form of "estimation by simulation". In their view, calibration principally differs from standard estimation methods because it allows the investigator to expand or restrict the range of features considered to be relevant.

Macroeconomists have increasingly calibrated their models since the 1980s mainly because the relatively complicated econometric approach that evolved in response to the rational expectations revolution and Lucas' critique of conventional econometric analysis

[57] Pagan (1994) contains a brief survey of the commonly used metric.

encouraged many researchers to opt for applied computable general-equilibrium models, which typically involve too many parameters (relative to the available data) to be efficiently estimated. Two other factors have further contributed to the accelerated use of calibration in macroeconomic analysis. First, the fast growth in computer technology during the past two decades has greatly enhanced numeric analysis and facilitated relatively sophisticated calibration techniques. Second, highly aggregated macroeconomic models do not often fit the historical data well because the aggregation process potentially loses information about individual agents whose collective behaviour the models seek to capture. The calibration method provides some flexibility in adapting the models to the data in a way that improves the quality of results they produce.

The application of calibration techniques to economic modeling has drawn many criticisms partly because it is relatively new and less standardized in the context of economic analysis, and partly because it was introduced into macroeconomic analysis by real-business-cycle theorists and has inadvertently inherited specific modeling techniques peculiar to this school of thought. There are legitimate criticisms too, just as the estimation technique and other conventional methods of economic analysis have been criticized on the basis of genuine weaknesses. First, critics argue that it is inappropriate to select model parameters from sources other than the model itself because the parameters consistent with a specific macroeconomic model may differ from those obtained from prior partial-equilibrium (often microeconomic) studies. Researchers sympathetic to the calibration technique dismiss this criticism by appealing to the philosophy that a theory is better supported when tested on information not used in its formulation.[58]

Like estimators, calibrators wish to have a close fit between their models and the actual data. But, while estimation tests models and rejects them when they do not fit the data, calibration adapts the model to reproduce key characteristics of the data. Critics argue that the adaptive nature of the calibration technique insulates the model from empirical

[58] This view is philosophically controversial, and some question its applicability to this specific practice in the calibration methodology. See Lipton (1991, chp. 8) and Hoover (1994).

confirmation or rejection, thus putting excessive confidence in theory to the neglect of empirical evidence. On the other hand, calibrators argue that calibration successfully adapts a model to the data only if the model closely reflects the structure of the system that generated the data. Gregory and Smith (1991, p. 30), for example, note that the calibration process often suggests fruitful modifications to the core model.[59] Hartley, Salyer and Sheffrin (1992) conclude that calibration can discriminate between competing models because a particular model cannot be successfully calibrated to data generated from different economic environments.[60]

Third, critics fault a common practice where real-business-cycle theorists typically calibrate their models to match second moments of key model variables rather than matching the actual historical evolution of the variables.[61] Lucas (1977, p. 218) defends this practice on the grounds that business cycles are qualitatively alike; therefore, a model's ability to capture individual business cycles is less important than its ability to characterize the distribution that produces these cycles. This is a typical case where critics confuse specific practice by real-business-cycle modelers with general calibration techniques. For example, Hoover (1995, p.40) notes that "*although calibration is consistent with appealing accounts of the nature and role of models in science and economics, of their quan[ti]fication and idealization, its practical implementation in the service of real-business-cycle models with representative agents is less than compelling.*".

Calibrators are called upon to develop a stern discipline that determines how calibration adjudicates between competing models in the same way that conventional econometric methods use hypothesis testing to adjudicate between competing theories.[62] However,

[59] For example, the inability of Kydland and Prescott's (1991) original real-business-cycle model to match the data prompted more complicated versions of essentially the same model that included heterogeneous labour (Kydland 1984), a banking sector (King and Plosser 1984), indivisible labour (Hansen 1985), variable capital intensity (Kydland and Prescott 1988), etc.

[60] The authors could not successfully calibrate a typical real-business-cycle model to mimic data generated from artificial economies that depart from key characteristics of the US economy.

[61] Real-business-cycle modelers typically focus on the variance of output and the covariance of hour and labour productivity.

[62] For example see Hansen and Sargent (1988), Manuelli and Sargent (1988), Watson (1993), Gregory and

Lucas (1980) and Prescott (1983) argue that the calibration method imposes discipline through the paucity of free parameters compared to standard estimation techniques that are able to exploit large numbers of free parameters.

Finally, the literature shows divergent views on whether calibration and estimation are complementary or competing analytical techniques. Critics of the calibration method argue that calibrated models may produce misleading results because of potential specification errors, omitted variable bias, and other deficiencies associated with incomplete model specification. Others insist that calibration is, at best, a first step that must be followed by setting down a metric (e.g. one induced by a likelihood function) that should be minimized and estimated through conventional econometric methods.[63] Thus, calibration should modify standard econometric methods only by incorporating restrictions implied by dynamic-optimization models. On the other hand, a number of researchers argue that calibration is a superior method and, once fully developed and standardized, should replace conventional estimation techniques. For example, Gregory and Smith (1991, p.3) conclude that calibration "... *is beginning to predominate in the quantitative application of macroeconomic models*". Kydland and Prescott (1991, p.167) argue that the estimation method flourished in the 1950s only because economists lacked the tools to construct stochastic computable general-equilibrium models.

The calibration methodology is still evolving and has great potential to facilitate the use of relatively sophisticated macroeconomic models to answer complicated policy questions. But it has important challenges too, particularly in terms of developing acceptable standards comparable to the principles that guide conventional estimation methods. It will likely take many years of intense research and debate to determine the calibration method's lasting contribution to econometrics in particular, and to the method of economic analysis in general.

Smith (1991), and Hoover (1994).

[63] For example, see Hansen and Sargent (1988, 9.293).

4.2 Measurement Convention

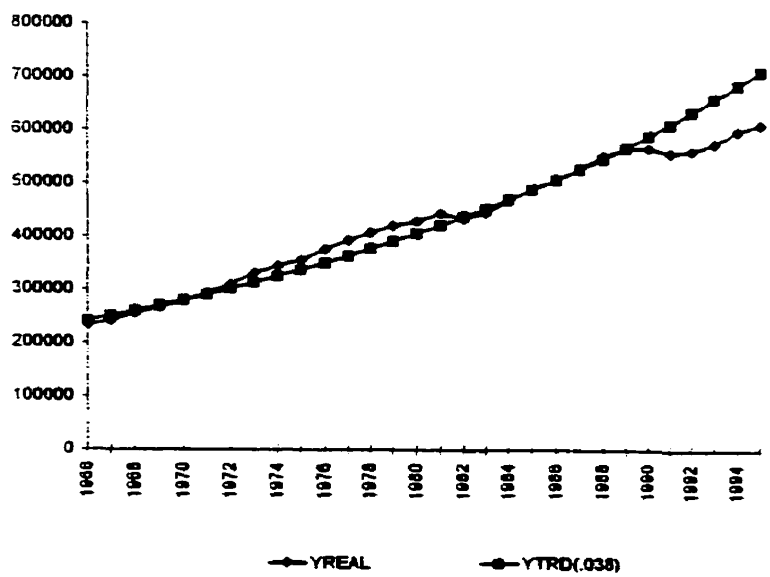
The model measures all real variables relative to the trend real output (*ytrd*),

$$ytrd_t = Y_0(1+ydot)^t \qquad (4.1)$$

where Y_0 is the level of real output in the base period (taken to be 1986) and *ydot* is the annual trend growth rate of real output, estimated to be 3.8 percent.[64] In general, if X is the constant-dollar measure at annual rate for the variable X, the model re-scales it as

$$x_t = \frac{X_t}{Y_0 * (1+ydot)^t} \qquad (4.2)$$

Fig. 4.1: Actual real output (Y) and its trend level (ytrd), measured in millions of dollars.



[64] The trend growth rate of real output (*ydot*) was calculated for the period 1960 to 1995. *Ydot* is zero in

The model measures all prices relative to the domestic absorption deflator at factor cost, *(pdfc)*. Thus, every price in the model is a relative price. Pdfc is exogenous; it is calculated from the historical data series.[65]

4.3 Measures of the Goodness of Fit

The model is calibrated to reflect key properties of the Canadian economy as described in the Bank of Canada's *CPAM* and *QPM*, and to mimic the historical data and current judgment of the Bank of Canada regarding the numerical steady-state values of some variables.[66] This section provides four sets of information with respect to the calibration of the model. First, Table 4.1 calculates the average *(avg)*, standard deviation *(std)*, and root mean square percent errors *(rmspe)* for selected endogenous variables based on a deterministic simulation that covers the period 1963-1995.[67] The root mean square percent errors are calculated relative to the averages of the historical series over the same period of time. Second, figs 4.2-4.3 in Appendix 1 compare deterministic simulation results for key variables with their respective historical series. Third, figs 4.4-4.5 below, and figs 4.6-4.9 in Appendix 2 illustrates the dynamic properties of the model based on responses of key model variables to a number of deterministic shocks. Finally, Appendix 5 contains the steady-state solution for the model.

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the steady-state model, and constant in the ***equilibrium***- and short-run ***disequilibrium*** models.

[65] The domestic absorption deflator at factor cost (pdfc) is defined by the relation pdfc*yd = pd*yd - tind, where pd*yd = py*y - px*x is nominal domestic absorption (i.e. nominal GDP less total exports), yd = y-x is real domestic absorption, and tind is indirect taxes.

[66] See Black and Rose (1997), Duguay and Longworth(1997); Poloz, Rose and Tetlow(1994) ; Black, Laxton, Rose and Tetlow(1994); and Coletti et. al (1996).

[67] The solution for the first three years and the last three years are dropped. The statistics are based on the solution for the period 1966-1992.

4.3.1 The Goodness of fit measured in terms of moments

Table 4.1 shows the average (*avg*) and standard deviation (*std*) based on a deterministic simulation over the period 1966-1992. All the figures are based on the disequilibrium model. The table also calculates two versions of root mean square percent error for selected variables. The first is the root mean square percent error relative to the historical data (*rmspe_hs*); the second is the root mean square percent error relative to the equilibrium values from the same deterministic simulation (*rmspe_eq*). The root mean square percent (simulation) error for the variable y is defined as,

$$rmspe = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{y_t^s - y_t^a}{y_t^a}\right)^2} \qquad 4.7[68]$$

where y_t^S is the simulated disequilibrium value of y_t and y_t^a is either the historical series for y_t (in the case of *rmspe* relative to the historical values) or the simulated equilibrium values of y_t (in the case of *rmspe* relative to equilibrium values). T = 27 is the number of periods included in the calculations(i.e. 1966 -1992). *Rmspe_hs* measures the average percentage deviation of the simulated disequilibrium values from the corresponding historical series. Therefore, small *rmspe_hs* indicates a good fit for the particular variable. On the other hand, *rmspe_eq* measures the extent to which the three sources of adjustments in the disequilibrium model (discussed in chapter 3 and reviewed in section 4.2) cause the disequilibrium variables to depart from their counterpart equilibrium values.

The results summarized in table 4.1 show that the model reasonably fits the actual data. The real output deviates from its historical values by 5.0 percent on average, and from its equilibrium values by 3.4 percent. For the unemployment rate, the figures are respectively

[68] The values of *rmspe* in Table 4.1 have been multiplied by 100 to express them in percentage form.

Table 4.1 Statistics on Variables from the Disequilibrium Model
(RMSPE refers to Root Mean Square Percent Error)

	AVERAGE	STANDARD DEVIATION	RMSPE RELATIVE TO HISTORICAL VALUES (rmspe_hs)	RMSPE RELATIVE TO EQUILIBRIUM VALUES (rmspe_eq)
C	0.623	0.026	10.44	3.34
FA	1.389	0.075	16.67	4.92
GB	0.449	0.063	12.13	7.90
INV	0.166	0.050	19.21	7.83
K	1.807	0.067	4.16	2.11
M	0.339	0.052	7.31	5.12
NFA	-0.422	0.065	21.22	13.01
PC	0.995	0.037	1.97	1.38
PFC	0.877	0.046	13.11	2.51
PK	1.128	0.203	8.89	2.60
PM	0.880	0.039	20.83	4.89
PX	0.867	0.036	21.40	3.46
PY	1.007	0.051	3.23	2.65
RNL	0.104	0.053	24.36	8.52
TD	0.262	0.047	32.71	1.54
TFP	0.873	0.040	4.86	3.35
U	0.079	0.026	13.74	15.28
W	0.626	0.045	4.18	3.40
X	0.346	0.037	3.85	3.61
Y	0.982	0.059	5.04	3.35
YD	0.528	0.047	9.36	2.25
YLAB	0.579	0.044	4.84	3.45
Z	0.946	0.223	21.38	3.46

1. All the statistics cover the period 1966-1992.
2. The root mean squared percent errors are calculated relative to historical values and equilibrium values.

13.7 percent and 15.3 percent. The relatively poor fit for the unemployment rate results from exogenously fixing the equilibrium unemployment rate at 7.5 percent (as proxy for the natural unemployment rate) in the deterministic simulation.[69] Total factor productivity deviates from the historical series by 4.9 percent, and from its equilibrium values by 3.4 percent. Exports and Imports deviate from their respective historical series by 3.9 percent and 7.3 percent, and from their equilibrium values by 3.6 percent and 5.1 percent respectively. Real consumption expenditures deviate from the historical data by 10.4 percent and from the equilibrium values by 3.3 percent; the corresponding figures for net investment expenditures (usually a difficult variable to explain) are 42.7 percent and 16.6 percent. The stock variables also fit the data reasonably well. Whereas financial assets and federal government debt-output ratio deviate from their respective historical series by more than 10.0 percent, the capital stock deviates by only 4.2 percent. Besides the federal debt-output ratio and net foreign assets, all the stock variables deviate from their equilibrium values by less than 5.0 percent. Net foreign assets show a relatively poor fit; it deviates from its historical series by 21.0 percent and from its equilibrium values by 13.0 percent.[70] The deviation of relative prices from the historical data range from 2.0 percent for consumption goods to 21.4 percent for the domestic price of exports. All the relative prices deviate from their respective equilibrium values by less than 5.0 percent.

Fig 4.2-4.3 in Appendix 1 extends the discussion on the goodness of fit by producing charts for selected variables based on the deterministic simulation. Just as in table 4.1, the charts compare values of the disequilibrium variables with their respective equilibrium solution and historical series. The charts produce similar conclusions as table 4.1. The simulated disequilibrium values for most variables are consistent with their equilibrium values and reasonably close to the actual historical data.

[69] The historical unemployment rate series varies between 1966 and 1992.
[70] The poor fit for net foreign assets partly reflects the fact that the model specifies its equation as a residual

4.3.2 Dynamic Properties of the Model

Figs 4.4-4.9 show dynamic responses of selected variables to temporary shocks to aggregate demand, inflation, the price of output, the real exchange rate, total factor productivity, and the slope of the yield curve. The results from the aggregate demand shock and inflation shock will be discussed below. The rest of the results are presented in Appendix 2.

A temporary Aggregate Demand Shock

A temporary 1.5 percent increase in Aggregate demand is implemented through an exogenous single-period increase in consumption expenditures by 2.0 percent and investment expenditures by one percent. The higher aggregate demand raises trend inflation (*pdot*) by a fifth of a percentage point and inflation in the price of consumption goods (*pcdot*) by half of a percentage point. As monetary policy tightens to return inflation to control, short-term nominal interest rates rise by nearly a percentage point raising the slope of the yield curve half of a percentage point. The output gap rises by 0.5 percent in response to the higher aggregate demand causing the price of output to rise initially by 0.2 percent and then 0.3% in the following year before declining steadily to control.[71] The higher output increases the tax base and allows the personal income tax rate to fall initially by 0.5 percent and then by 1.2 percent by the second year before rising gradually back to control. The capital-output ratio initially falls by a quarter of a percent because of the increase in real output. However, this ratio rises and overshoots control by the third year due to the cumulative effect of the higher investment spending; it subsequently declines steadily to control by the ninth year. The higher interest rates cause the real exchange rate to appreciate by just over 0.1 percent. The higher output and stronger dollar raise imports while the stronger dollar reduces exports, causing net exports to decline sharply before rebounding to control by the third year. Higher interest rates and

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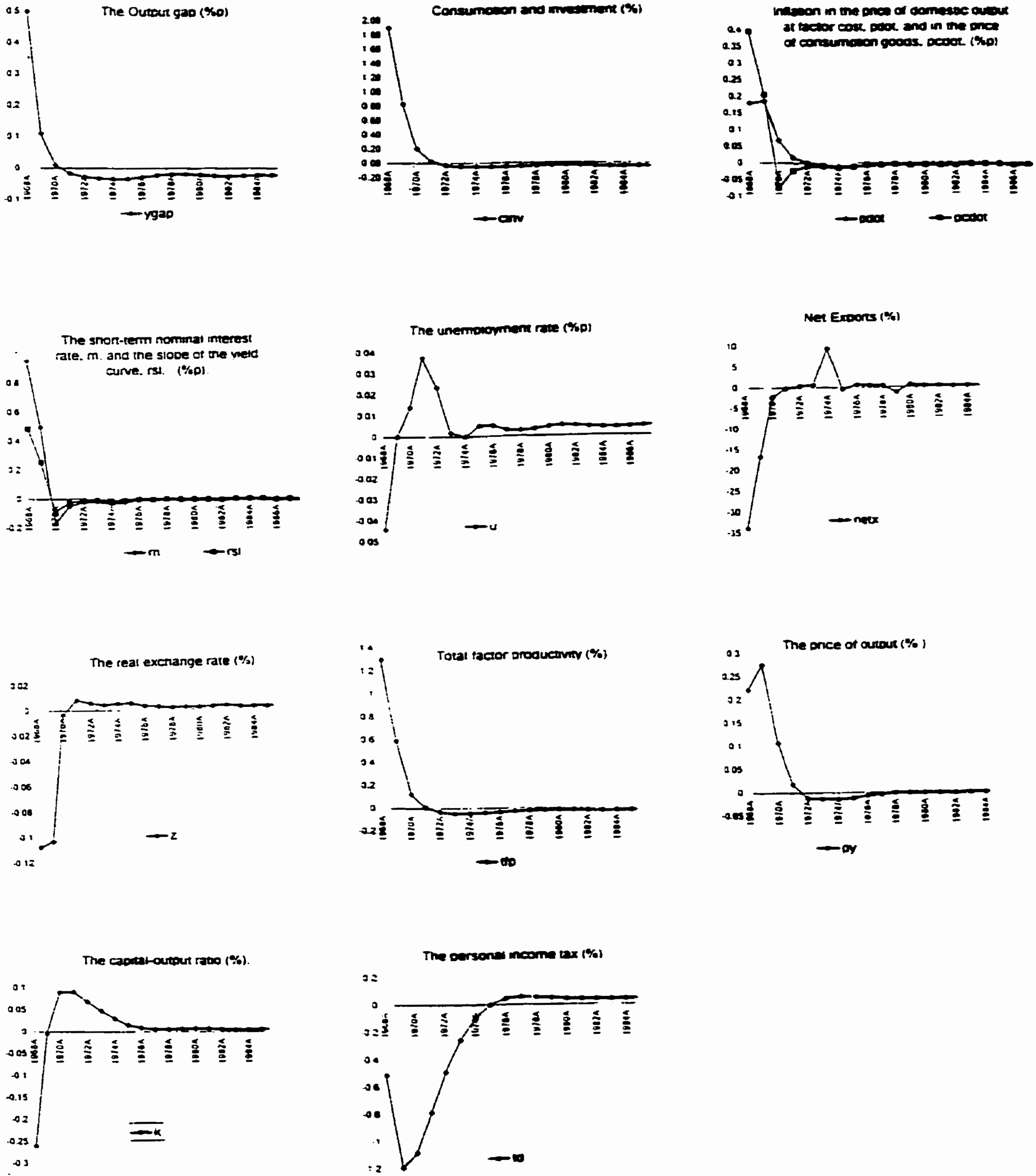
in the stock identity.

[71] The output gap measures the excess real output over trend output. Trend output is proxied by the

Figure 4.4 Responses of selected variables to a temporary aggregate demand shock
(% is percent shock minus control; %p is percentage points shock minus control)



Hodrick-Prescott trend for historical output.

higher import prices eventually reduce investment and consumption expenditures and cause aggregate demand to start falling. Four years after the shock, aggregate demand is back to control, and so are the rate of inflation, interest rates, the exchange rate and the output gap. The aggregate demand shock has a more persistent effect on the stock variables. The capital-output ratio and the personal income tax rate (which is the instrument used to target the federal debt-output ratio) remain above control for approximately four more years.

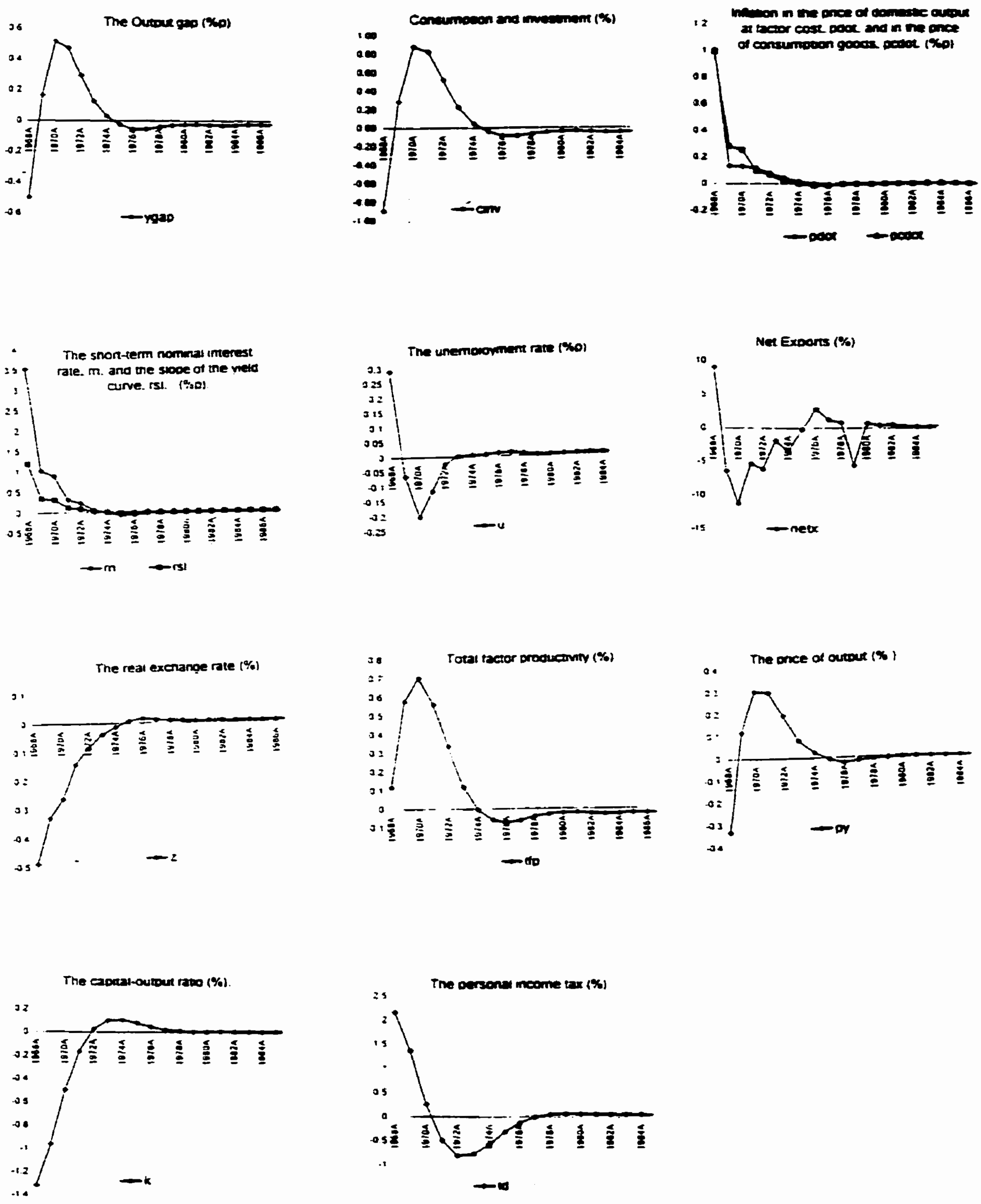
A temporary increase in the rate of inflation

The Phillips curve is shocked to raise the rate of inflation by one percentage point in a single year. This raises inflation in the price of consumption goods by one percent. As monetary policy tightens to return inflation to control, short-term interest rates rise by 1.2 percentage points, raising the slope of the yield curve by 3.5 percentage points. The higher interest rates reduce aggregate demand by 7% and appreciate the real exchange rate by 0.5 percent relative to control.

The initial fall in aggregate demand reduces the output gap by 0.5 percent and raises the unemployment rate by 0.3 of a percentage point.[72] The capital-output ratio falls by 1.3 percent below control due to lower investment expenditures caused by higher interest rates. The lower tax base tightens the fiscal constraint and raises the personal income tax rate by 2 percentage points above control.

As the rate of inflation declines and monetary policy eases, aggregate demand gradually returns to control bringing with it all the other variables. After rising by nearly a percentage point in response to the original increase in inflation, net exports fall by a percentage point below control by the third year before rising gradually back to control.

Figure 4.5 Responses of selected variables to a temporary increase in the rate of inflation.
(% is percent shock minus control; %p is percentage points shock minus control)



[72] See footnote no. 8.

Aggregate demand, the unemployment rate, the output gap and the personal income tax rate all overshoot their respective controls slightly before converging smoothly back to control by the eighth year.

4.4 Calculation of Structural Shocks for Stochastic Simulation

Most studies using calibrated models to evaluate alternative monetary policy rules have based the distribution of shocks on the properties of either the residuals from estimated reduced-form equations or Vector Autoregressive (VAR) models under the assumption that the shocks are independently distributed.[73]

Black, Macklem and Rose(1997) use a different approach to define structural shocks in their model. This chapter follows their method closely to calculate structural shocks for stochastic simulations in chapters 5 and 6. The first step involves estimating a six-variable VAR that corresponds with the six variables to be shocked in the model. The estimated VAR is used to produce impulse responses to innovations in each of the six variables. In turn, the impulse responses are used to define structural shocks in a way that enables the nonlinear structural model to produce impulse responses that have similar correlation pattern as those generated from the linear VAR.

4.4.1 The Vector Autoregression Model (VAR)

The VAR includes potential output (*yp*), the relative price of exports (*pxrow*), the sum of consumption and investment (*c+i*), the relative price of output (*py*), the real exchange rate (*z*) and the slope of the yield curve (*rsl*). *Yp* is proxied by the Hodrick-Prescott trend of the historical real output series. *Pxrow* is proxied by the product of the U.S. import price index and the real exchange rate divided by the numeraire price in the model (the price of

[73] See Black, Macklem and Rose (1997).

domestic absorption at factor cost, *pdfc*). Innovations in *pxrow* are interpreted as shocks to world commodity prices. *C+i* is the ratio of the sum of consumption and investment expenditures to trend output; innovations in *c+i* are interpreted as aggregate demand shocks. *Py* is the ratio of the implicit GDP deflator to *pdfc*; innovations in *py* are interpreted as aggregate supply shocks. *Z* is the real exchange rate with the G7 countries; innovations in z are interpreted as shocks to the confidence of foreign investors. *Rsl* is defined as the difference between the 90 day treasury bill rate and the 10 year government of Canada bond rate; innovations in *rsl* are interpreted as, among other things, shocks due to innovations in central bank's policy and shocks from international financial markets. *Rsl* enters the VAR in levels; *cinv*, *z* and *yp* enter in log levels; and *py* and *pxrow* enter in the first difference of logs.[74]

Some restrictions are imposed on the structure of the VAR based on stylized facts about structural relationships in the economy. First, the VAR model treats *yp* and *pxrow* as exogenous. However, each of them evolves as a function of its own lagged values. This restriction is imposed on the structure of the VAR prior to estimation. It reflects the fact that potential output is typically affected by factors such as changes in productivity and resource endowment while commodity prices respond mostly to external factors. Thus, the other VAR variables have practically little effect on the dynamics of these two variables. The other restrictions are imposed on the estimated coefficients matrix and correlation matrix ex-post. First, there is no contemporaneous cross-correlation between the two exogenous variables, *yp* and *pxrow*. This restriction ensures that first-round effects of commodity price shocks do not affect potential output, and vice versa.[75] Finally, the Moving Average representation of the VAR is identified by imposing the Wold causal ordering,

yp, pxrow, c+i, py, z, rsl. (4.8)[76]

[74] The log levels and first difference of logs made the designated variables stationary.
[75] The previous restriction that exogenizes *py* and *pxrow* effectively takes care of this restriction. However, the restriction is also explicitly imposed on the residual correlation matrix (CORR).
[76] Black, Macklem and Rose(1998) impose a further restriction that makes py independent of the lagged

The causal ordering (4.8) makes each variable responsive to contemporaneous innovations in variables that precede it but responsive to only lagged innovations in variables it precedes in the ordering. The only exceptions are *yp* and *pxrow* which are exogenous and therefore do not respond to innovations in any of the other variables. Thus, consumption and investments expenditures respond to changes in inflation, the real exchange rate, and monetary policy with a lag. On the other hand, the monetary authority looks at the contemporaneous state of the entire economy before making changes to monetary policy.

The first-order vector Autoregressive model, VAR(1), produced a reasonable fit for the data.[77] The VAR(1) was estimated over the period 1965-1990 after imposing the restrictions discussed above. Since potential output (*yp*) and the relative price of exports (*pxrow*) are exogenous in the VAR, their coefficients were estimated separately by fitting an AR(1) to each of them. Table 4.2 contains the estimation results.

Although some of the individual t-values are small, the coefficient of determination (R-squared) show that the first-order vector autoregressive model explains approximately 90 percent of the variations in the sum of consumption and investment expenditures and in output prices, about 70 percent of the variation in the real exchange rate, and about 50 percent of the variation in the slope of the yield curve.

4.4.2 Deriving Impulse Responses from the Linear VAR Model

The coefficient matrix COEFF and the correlation matrix CORR summarize the estimated results in table 4.2. After imposing the appropriate restrictions, the matrices are

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values of pxrow. This restriction reflects the view that the large effects of the oil-price shocks on inflation in 1973 and 1978 were related more to the Bank of Canada's accommodating policy than to any strong structural link between relative prices and the aggregate price level. The thesis does not include this restriction because some of the impulse responses showed small improvements without them.

[77] The VAR(1) model was selected on the basis of the Schwartz and Ackaike information criteria after examining a number of models.

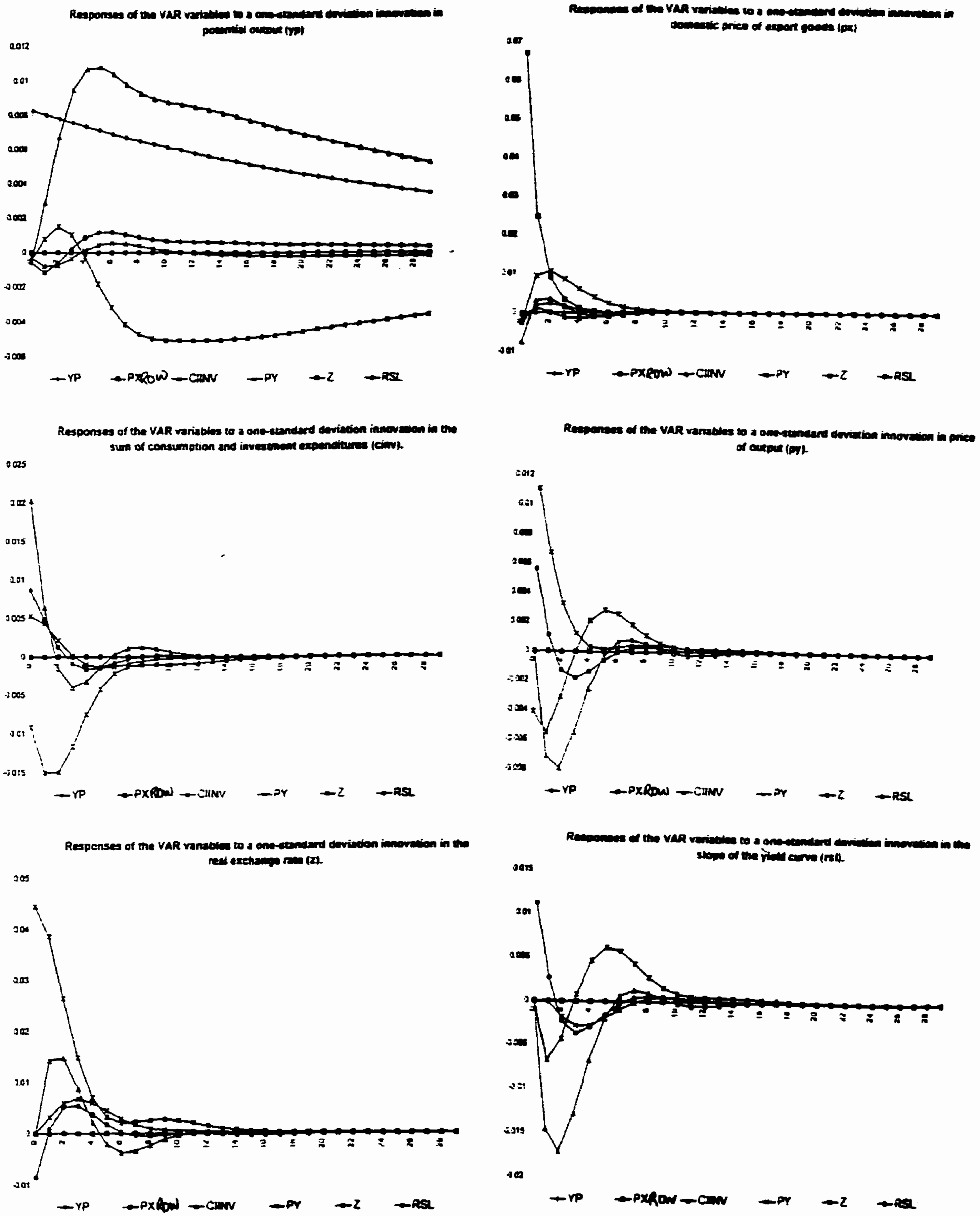
TABLE 4.2 RESULTS FROM ESTIMATION OF VAR
(The t-values are in parentheses)

	LCINV+	D(LPY)	LZ	RSL	LYP	D(LPXROW)
LCINV(-1)+	0.89	0.08	-0.17	0.17		
	(7.82)	(1.31)	(-0.67)	(2.63)		
D(LPY(-1))	0.04	0.64	0.08	0.00		
	(0.17)	(4.36)	(0.14)	(0.02)		
LZ(-1)	0.07	0.07	0.75	0.06		
	(1.20)	(2.12)	(5.68)	(1.92)		
RSL(-1)	-1.30	-0.01	-0.60	0.24		
	(-3.55)	(-0.05)	(-0.76)	(1.18)		
CONSTANT	-0.04	0.03	0.00	0.02		
	(-1.28)	(1.38)	(0.04)	(1.22)		
LYP(-1)	0.33	0.07	0.09	-0.11	0.97	
	(1.74)	(0.66)	(0.23)	(-1.06)	(27.66)	
D(LPXROW)(-1)	0.10	0.18	-0.01	0.05		0.37
	(1.62)	(5.35)	(-0.05)	(1.60)		(2.13)
R-squared	0.89	0.87	0.67	0.47		

+ CINV is the sum of consumption and investment expenditures, C+I

used to derive impulse responses to one-standard deviation innovation in each of the six variables. Appendix 3 discusses the derivation of the impulse responses in detail. Fig 4.10 below shows that the impulse responses are consistent with economic theory. The rest of this section discusses the impulse responses of the six VAR variables to innovations in potential output, aggregate demand and the slope of the yield curve.

Figure 4.10 Impulse responses to one-standard deviation innovation in each of the variables in the VAR.



When potential output (*yp*) is increased by 0.8 percent (which is the equivalent of one-standard deviation), none of the other variables responds contemporaneously. The sum of consumption and investment (the proxy for aggregate demand) rises by 0.5 percent after one year and peaks at 1.4 percent by the fourth year. The higher potential output raises desired investment spending and the levels of income, disposable income and consumption. The shock reduces excess demand pressure causing the relative price of output to fall initially before rising slowly back to control. As excess demand pressure falls, monetary policy eases, causing the slope of the yield curve to fall below control in the first three years, and the real exchange rate to depreciate for the first two years. The shock has permanent effects on all the variables except the exogenous commodity prices, *pxrow*. Potential output itself remains 0.6 percent permanently higher; the sum of consumption and investment becomes 0.9 percent permanently higher, and the real exchange rate permanently appreciates by 0.3 percent. The price of output and the slope of the yield curve stay slightly higher than their initial levels.

The sum of consumption and investment expenditures (*cinv*) serves as proxy for aggregate demand. When *cinv* is raised by 2.6 percent (the equivalent of one-standard deviation), the relative price of output rises by 0.5 percent in the first year and declines towards the initial level thereafter. Monetary policy tightens in response to the higher inflation, causing the slope of the yield curve to rise by a percentage point. The real exchange rate also appreciates by one percent in the first year and by 1.5 percent in the second and third years before depreciating gradually to its initial level by the sixth year. Almost all the variables return to their initial levels within ten years after the shock.

An exogenous change in the slope of the yield curve represents a contractionary monetary policy shock. When the short term interest rate is raised to achieve a percentage-point increase in the slope of the yield curve, the real exchange rate appreciates by 0.7 percent in the first year. The higher interest rates reduce the sum of consumption and investment by 2.3 percent in the first two years following the shock. The lower aggregate demand

and real exchange rate appreciation reduce the relative price of output from the second year to the fifth year before returning to control by the seventh year. As the initial shock wears off and the slope of the yield curve returns to control, the real exchange rate completely reverses the initial 0.7 percent depreciation and overshoots its control by 0.5 percent by the fifth year. This causes the relative price of output and the sum of consumption and investment expenditures to overshoot slightly before returning to their respective control levels. All the variables converge to their control levels within ten years after the shock.

Appendix 4 describes how the impulse response functions are used to define structural shocks in the non-linear model such that the model produces impulse responses that have similar correlation patterns as those produced by the linear VAR. The process involves performing deterministic simulations on the structural model, and introducing the impulse responses into these simulations to derive ("back out") estimates of structural shock terms that are later combined with random shocks to define the ultimate shocks in the structural model. This approach to defining structural shocks has important advantages over conventional methods. First, the properties of the shocks benefit from the richness of the structural model from which they are derived. Second, it allows the auto-correlation and cross-correlation structure of the shocks to be determined by their historical correlation. As a result, the shocks are more likely to capture the true correlation pattern of structural shocks facing the economy; this makes it unnecessary to make arbitrary assumptions such as independence. Like other methods, however, this approach is not capable of isolating pure structural shocks from the effects of countercyclical monetary and fiscal policies. As Appendix 4D explains, this problem is addressed by truncating the impulses from each shock after two years. The final structural shocks appear in the equations that determine the six VAR variables in the short-term (disequilibrium) model.

CHAPTER 5 SIMULATION RESULTS FROM THE MODEL

This chapter discusses results from stochastic simulations based on versions of the model with one percent, three percent, five percent and seven percent inflation targets. The simulation at each inflation target involves 100 replications of history over the period 1960-95. The model simulates different shocks for each of the 100 replications. It also simulates different shocks for each period within a replication. However, it repeats the same set of shocks for all four inflation targets. Therefore differences in the solution exclusively reflect the effects of different inflation targets.

For each inflation target, the average and standard deviation for the period 1966-92 are further averaged over the 100 replications to produce a '*grand average*' and a "*grand standard deviation*" for each model variable.[78] In subsequent discussion, the values and standard deviation for each variable refer to these *grand averages* and *grand standard deviations* respectively. Tables 5.1 and 5.2 show the percentage change in selected variables as the monetary authority reduces the inflation target from 7 percent to 1 percent at two percentage-point intervals.

Chapter 3 discusses the three levels of structural relationships in the model, and shows that this stratification creates three distinct sub-models: the steady-state model, the equilibrium model and the disequilibrium model. The steady-state model represents long-run equilibrium relationships that abstract from all forms of dynamic adjustments. The *equilibrium model* represents medium-term structural relationships including limited dynamics from stock-flow relationships in the economy. The disequilibrium model adds four types of short-run, dynamic adjustments to those present in the equilibrium model.

The model assumes that each inflation regime is permanent. Therefore tables 5.1 and 5.2

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[78] The model has a maximum lag of 3 years and a maximum lead of two years. It therefore produces solution for the period 1963-1993. The average and standard deviation do not include the first three periods (1963-65) and the last period (1993).

estimate the *average* effect of inflation reduction over the period 1966-92. The empirical literature shows no consensus on the relative durability of the costs and benefits of inflation reduction. Analysts and policymakers often assume that the costs are relatively short lived. One of the important extensions to this thesis is to decompose the figures in table 5.1 into short-term and medium-term effects by dividing the simulation period 1963-1993 into shorter sub-periods. Subsequent analyses in this thesis describe changes in the disequilibrium model as short-term in nature, and changes in the equilibrium model as medium- to long-term in nature.

The model focuses more on the costs of inflation reduction than it does on its benefits. Although the model includes benefits in the form of lower equilibrium user cost of capital and larger financial assets, it does not explicitly include other important sources of benefits such as lower shoe-leather costs, lower menu costs and the price-signal effect which have featured prominently in the debate on the benefits of inflation reduction. The simulation results therefore reflect more closely the *gross* costs, rather than the net costs (or net benefits), of inflation reduction.

5.1 Short-Term Macroeconomic Effect of Lowering the Inflation Target

The disequilibrium model adds four types of adjustments to those present in the equilibrium model. The first type of adjustment reflect the gradual nature of agents' responses to shocks due to rigidities arising from such constraints as irreversibility of certain investment decisions and past contracts still in effect. The second type of adjustment reflects the fact that agents' expectations are partly adaptive. Agents update their perception of the future and adjust their behaviour accordingly as they obtain more information. The third type of adjustment arises from endogenous reaction of monetary and fiscal policies to cyclical movements in the economy.[79] Finally, the disequilibrium

[79] Monetary policy has limited effect on variables in the equilibrium model. These effects are presented in table 5.2 and discussed in section 5.2. The short-term (disequilibrium) model embodies all the effects from the equilibrium model, as well as those arising from the four disequilibrium adjustments. Therefore, the results presented in table 5.1 reflect the combined effect of monetary policy working through the

model includes shock terms in all behavioural equations. These shock terms provide avenue to introduce exogenous shocks to the model.

Monetary policy reacts proportionately to the two-year forecast inflation gap - the deviation of the two-year inflation forecast for the consumer price index from the target set by the monetary authority. When stochastic shocks raise the forecast inflation for future periods by a certain magnitude, this change will represent a proportionately larger inflation gap when inflation is being target at a low level than when inflation is being targeted at a relatively high level. Therefore, for any given increase in inflation expectations, monetary policy will respond more vigorously if the inflation target is low than when the inflation target is high. This asymmetry of monetary policy reaction to inflation shocks at different inflation targets will, in turn, produce asymmetric macroeconomic effect at different inflation targets.

Among other factors, inflation expectations depend on the extent to which agents perceive monetary policy to be credible, and the extent to which structural rigidities inhibit smooth and speedy adjustment of the economy to stochastic disturbances.[80] A positive forecast inflation gap attracts a tighter monetary policy that results in higher interest rates and a steeper yield curve. The higher interest rates raise short-term borrowing costs and dampen real investment and consumption expenditures. Higher interest rates also appreciate the dollar and thereby raise import expenditures and reduce exports. The resulting decline in net exports combines with the fall in consumption and investment expenditures to reduce aggregate expenditures. On the other hand, the higher interest rates raise the stock of financial assets which, in turn, increases consumption

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equilibrium model and through the extra four adjustment terms.

[80] The equations that determine agents' inflation expectations assign about 20 percent weight to the monetary authority's inflation target. This figure is low, and reflects a perception of low credibility that often characterizes the initial stages of inflation low-inflation targeting. It also reflects the fact that this thesis focuses more on the costs than the benefits of inflation reduction. In CPAM, the inflation target receives a weight of 10 percent in agents' inflation expectations. Two features in the model reflect structural rigidities. First, the adjustment terms discussed in chapter 4 and included in behavioural equations in the short-term (disequilibrium) model. Second, the lags and leads built into the model, including the partially adaptive nature of the inflation expectation process.

expenditures. This wealth effect partly offsets the decline in aggregate expenditures.

On the supply side, the fall in net investment spending reduces the stock of capital and causes future output to decline.[81] Total factor productivity falls if aggregate demand declines relative to the level of output. The lower total factor productivity reduces the relative wage, output and employment. Symmetrically, total factor productivity rises if aggregate demand rises relative to output. In this case, real output, the relative wage and employment all rise.

When lower aggregate demand reduces real output and raises the unemployment rate, it also raises net government transfers to the public, which combines with the higher interest costs to raise the federal government debt-output ratio. Maintaining a fiscal balance in the face of a greater debt burden and a smaller tax base requires an increase in the income tax rate, which serves as instrument for endogenous fiscal policy. The higher income tax combines with the lower labour income to reduce disposable income and real consumption expenditures.

As mentioned earlier in the chapter, the nature and intensity of these dynamics hinge critically on the sign and magnitude of the two-year forecast inflation gap, which determines the direction and intensity of monetary policy. Tables 5.1 and 5.2 show the percentage change in selected variables as the monetary authority reduces the inflation target from 7 percent to 1 percent at two percentage-point intervals. As explained earlier in the chapter, the values and standard deviation for variables in tables 5.1 and 5.2 refer to the *grand averages* and *grand standard deviations* respectively, calculated from 100 replications of history.

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[81] The Cobb Douglas production function determines the level of output according to the existing capital stock and employment rate. The labour force is normalized to one, and the employment rate is defined as

Table 5.1 Effect of a Two Percentage-Point Reduction in Inflation Target (The figures are based on the disequilibrium model)

	7%-5%	5%-3%	3%-1%
C	-2.092	-2.377	-3.486
FA	1.469	1.406	1.062
GB	1.372	1.535	2.065
GTR	2.050	2.403	3.647
INV	-0.943	-1.777	-3.185
K	-0.146	-0.737	-1.062
NETX	-3.304	-5.126	-6.371
NFA	-4.204	-5.734	-6.193
NRP	na	na	na
PCDOTE+	0.371	0.545	0.704
PDOTE+	0.285	0.453	0.615
PCDOT+	0.151	0.238	0.277
PDOT+	0.141	0.213	0.259
R	0.489	0.673	1.011
RL	0.062	0.058	0.247
RN	-1.481	-1.114	-0.858
RNL	-1.928	-1.745	-1.576
RSL	0.382	0.546	0.686
TD	0.087	0.085	0.214
TFP	-0.980	-0.927	-1.495
U	0.324	0.458	0.539
W	-1.270	-1.449	-2.477
Y	-1.239	-1.484	-2.290
YD	-1.030	-1.192	-2.137
YLAB	-1.611	-1.896	-3.053
Z	-0.367	-0.297	-1.473

+ Pdote measures the two-year forecast trend inflation gap for 5 percent, 3 percent and 1 percent inflation targets. Pcdote measures the corresponding two-year forecast inflation gap in the consumer price index. Pdot and pcdot measure the actual gaps.

one minus the unemployment rate.

5.1.1 Effect of Reducing Inflation Target from Seven Percent to Five Percent

When the monetary authority reduces the inflation target from 7 percent to 5 percent, inflation expectations fall from 7.1 percent to 5.4 percent for the consumer price index, and from 7.1 percent to 5.3 percent for trend inflation. However, the forecast inflation gap rises from 0.14 percentage points to 0.37 percentage points. Thus, even though the lower inflation target reduced inflation expectations and actual inflation, it nevertheless, raised both measures of inflation relative to the lower inflation target. As monetary policy tightens to eliminate the higher forecast inflation gap, short-term real interest rates rise 49 basis points compared with only 6 basis points for long-term rates. On the other hand, short-term and long-term nominal rates fall by 1.5 percentage points and 1.9 percentage points respectively in response to the lower inflation expectations. These changes in interest rates raise the slope of the yield curve by 38 basis points.

The higher real interest rates reduce real investment expenditures by one percent, which in turn causes a cumulative reduction of 0.2 percent in the capital stock. Moreover, the higher real interest rates contribute to the 2.1 percent decline in real consumption expenditures, and also combine with the lower inflation rate to appreciate the real exchange rate by 4 percent. The dollar appreciation offsets the positive trade effects from lower domestic inflation, so that net exports fall by 3.3 percent. Total factor productivity falls by 1.0 percent because the decline in consumption expenditures, investment expenditures and net exports reduce aggregate demand relative to output and cause real output to fall by 1.2 percent. As a result, the unemployment rate rises by 0.3 percentage points, the relative wage falls by 1.3 percent and labour income falls by 1.6 percent. On one hand, the higher unemployment rate and lower aggregate expenditures reduce the tax base and raise government transfers to the public by 2.0 percent. On the other hand, the higher real interest rates raise interest costs on the higher national debt. Together, the two forces create a potential budget deficit that requires the fiscal agent to raise income taxes by nearly a percentage point to balance the budget. Consequently, disposable income falls by just over one percent, contributing further to the 2.1 percent decline in real consumption expenditures.

5.1.2 Effect of Reducing Inflation Target from Five Percent to Three Percent

The third column of table 5.1 shows the effect of reducing the inflation target from 5 percent to 3 percent. The two-percentage point reduction in the inflation target reduces inflation expectations for the consumer price index from 5.4 percent to 3.6 percent. Similarly, expectations for trend inflation fall from 5.3 percent to 3.5 percent. The lower inflation expectations reduce short-term and long-term nominal interest rates by 1.1 percent and 1.8 percent respectively as agents build lower inflation into their decisions.

However, inflation expectations fall by less than the two-percentage points decline in the inflation target, and so the forecast inflation gap rises from 0.4 percent to 0.6 percent. Although lower inflation expectations associated with the lower inflation target tend to reduce interest rates in general (and long-term rates in particular), the tightening of monetary policy to shrink the forecast inflation gap raises the slope of the yield curve by 55 basis points as it allows short-term nominal interest rates to fall by only 1.1 percentage points compared with the 1.8 percentage-points decline in long-term nominal interest rates.

The figures in the table show that the policy produces a *recession effect* and a *capital stock effect* that are stronger but qualitatively similar to the case where the inflation target was lowered from 7 percent to 5 percent. Net investment expenditures fall by 1.8 percent in real terms, real consumption expenditures fall by 2.4 percent, and net exports fall by 5.13 percent due in part to the 0.3 percent real exchange rate appreciation resulting from higher real interest rates. The lower aggregate demand reduce real output by 1.5 percent and raises the unemployment rate by half of a percentage point.

5.1.3 Effect of Reducing Inflation Target from Three Percent to One Percent

Reducing the inflation target further from 3 percent to 1 percent produces the strongest macroeconomic effect among the three cases shown in table 5.1. At one percent inflation target, the forecast inflation gap is 0.7 percentage points, up from about 0.5 percentage points when the inflation target was set at 3 percent. The higher forecast inflation gap reflects high inflation expectations relative to the inflation target.[82]

As section 5.1 explains, monetary policy reacts proportionately to the two-year forecast inflation gap, which is the deviation of the two-year inflation forecast for the monetary authority's inflation target. When stochastic shocks raise the forecast inflation for future periods by a certain magnitude, this change will represent a proportionately larger inflation gap when inflation is being target at a low level than when inflation is being targeted at a relatively high level. Therefore, for any given increase in inflation expectations, monetary policy will respond more vigorously if the inflation target is set low than when the inflation target is high. This asymmetry of monetary policy reaction to inflation shocks at different inflation targets translates into asymmetric macroeconomic effect of disinflation at different inflation targets. These effects clearly show throughout sections 5.1.1 to 5.1.3, with the macroeconomic effects of disinflation rising from the case where inflation was originally target at 7.0 percent to the case where the target was set at 3.0 percent.

The tighter monetary policy that the high forecast inflation gap attracts largely offsets the effect that lower inflation expectations would have on interest rates. Consequently, short-term nominal interest rates fall by only 86 basis points compared with the drop in long-term rates by 1.6 percentage points; the slope of the yield curve rises by 69 basis points. Short-term real interest rates rise by a full percentage point; however, long-term real rates rise by only 25 basis points as they respond more strongly to lower inflation expectations.

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[82] Although expectations for both trend inflation and consumer-price inflation fall at the lower inflation target, the forecast inflation gap rises reflecting the fact that inflation expectations did not fall enough to

The higher interest rates reduce real investment expenditures and the capital stock by 3.2 percent and 1.1 percent respectively. The higher interest rates also appreciate the dollar by 1.5 percent and contribute to the 6.4 percent decline in net exports. Total factor productivity falls by 1.5 percent reflecting the shortfall in aggregate demand relative to potential output. The lower aggregate demand reduces real output by 2.3 percent and raises the unemployment rate by 0.5 percentage points. The relative wage and labour income fall by 2.5 percent and 3.1 percent respectively prompting a 3.6 percent increase in public transfers that combines with the high interest costs to raise the national debt-output ratio by 2.1 percent. The shrinking tax base and higher government transfers creates a budgetary imbalance that requires income taxes to rise by 0.2 percentage points. Disposable income falls by 2.1 percent and contributes to the 3.5 percent decline in real consumption expenditures.

5.2 Medium- to Long-Term Macroeconomic Effect of Lowering the Inflation Target

The equilibrium risk premium built into long-term interest rates in the model depends positively on the *excess inflation gap* defined as the rate of inflation in excess of 3 percent.[83] When monetary policy targets a lower inflation rate, the lower inflation expectations reduce the equilibrium risk premium and cause interest rates to fall. The lower interest rates and lower prices for investment goods reduce the equilibrium user cost of capital and raise the equilibrium rate of investment and the equilibrium capital stock. The higher equilibrium capital stock tends to raise future output and employment.

The policy-induced inflation reduction also generates equilibrium demand-side effects that may partially or fully offset the supply-side effects discussed above. Lower equilibrium interest rates reduce the equilibrium stock of financial assets and generate negative wealth effects that reduce equilibrium consumption expenditures. On the other

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match the decline in the target.

[83] As chapter 3 notes, the 3 percent threshold is arbitrary. However, the monetary policy debate in the

hand, the lower equilibrium interest rates may offset the effect of lower domestic prices and depreciate the equilibrium real exchange rate, thereby raising equilibrium net exports. The equilibrium total factor productivity rises when equilibrium aggregate demand rises faster than equilibrium output, and falls when the reverse occurs. In the former case, the equilibrium unemployment rate falls and equilibrium labour income rises. The lower equilibrium unemployment rate and larger tax base generate endogenous fiscal responses similar to those discussed with respect to the disequilibrium model in section 5.1 above.

5.2.1 Medium to Long-Term Effect of Two Percentage-Point Reduction in Target Inflation

When the inflation target is reduced two percentage points from 7 percent to 5 percent, equilibrium short-term and long-term nominal interest rates fall by 2 percentage points and 2.1 percentage points respectively causing the equilibrium slope of the yield curve to rise by 8 basis points. However, the lower inflation expectations reduce inflation premiums by 8 basis points causing equilibrium long-term real interest rates to fall by the same amount. The lower inflation translates into a 0.2 percent decline in the price of investment goods. The lower equilibrium interest rates combine with the lower price of investment goods to reduce the equilibrium user cost of capital by 0.23 percent, raising the equilibrium rate of investment and the equilibrium capital stock by 1.16 percent and 1.0 percent respectively.

Lower equilibrium interest rates reduce equilibrium financial assets by 0.3 percent and contribute to the 0.6 percent decline in equilibrium consumption expenditures. However, lower equilibrium domestic prices associated with the lower inflation rate offset the effect of lower interest rates to appreciate the dollar by 0.1 percent and raise net exports by 1.3 percent. The 0.6 percent decline in equilibrium total factor productivity signifies deficient aggregate demand relative to potential output. The lower aggregate demand reduces equilibrium output by 0.3 percent but has negligible effect on the equilibrium

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1990s justifies that figure.

Table 5.2 Medium-Term Macroeconomic Effects of Inflation Reduction[1]

	7%-5%	5%-3%	3%-1%
C.EQ	-0.63	-0.66	-0.86
CC.EQ	-0.23	-0.21	-0.23
FA.EQ	-0.25	-0.24	-0.30
GB.EQ	0.00	0.00	0.00
HW.EQ	-0.16	-0.19	-0.24
INV.EQ	1.16	1.01	1.04
K.EQ	0.99	0.82	0.91
NETX.EQ	1.30	1.11	1.09
NFA.EQ	2.37	1.80	1.90
PK.EQ	-0.15	-0.15	-0.18
R.EQ	0.00	0.00	0.00
RL.EQ	-0.08	-0.08	-0.08
RN.EQ	-2.03	-2.03	-2.03
RNL.EQ	-2.14	-2.13	-2.13
RSL.EQ	0.08	0.07	0.08
RT.EQ	-0.08	-0.08	-0.08
TD.EQ	0.11	0.11	0.24
TFP.EQ	-0.58	-0.56	-0.70
TW.EQ	-0.18	-0.20	-0.25
U.EQ	0.01	0.01	0.02
W.EQ	-0.35	-0.38	-0.53
Y.EQ	-0.26	-0.30	-0.41
YLAB.EQ	-0.36	-0.40	-0.55
Z.EQ	-0.09	-0.08	-0.11

1. The figures in this table are based on the Equilibrium model.

unemployment rate.[84] The decline in equilibrium output and equilibrium total factor productivity reduce both the equilibrium relative wage and equilibrium labour income by 0.4 percent contributing further to the 0.6 percent decline in equilibrium consumption expenditures.

The equilibrium effect of reducing the inflation target from 5 percent to 3 percent is almost identical to the case where the target is reduced from 7 percent to 5 percent. Reducing the inflation target from 3 percent to 1 percent yields larger but qualitatively similar results as the other two cases.

5.3 How Inflation Reduction Affects Macroeconomic Stability

The literature reviewed in chapter 2 does not show a consensus on the relationship between the level of inflation and variability of inflation and other key macroeconomic variables. Table 5.3 contains the standard deviation associated with the simulation results presented in tables 5.1 and 5.2. It shows how the average standard deviation for selected variables change as the monetary authority reduces the inflation target from 7 percent to 1 percent at two percentage-point intervals. As explained earlier in the chapter, the standard deviation for each variable refers to the *grand standard deviation* calculated from 100 replications of history. The table normalizes the standard deviation for each variable to be one when the inflation target is set at 7 percent.

The trend inflation (*pdot*) and consumer-price inflation (*pcdot*) both tend to be a little more volatile as the inflation target is reduced from 7 percent to 5 percent, and further

[84] The insensitivity of equilibrium unemployment rate to the decline in equilibrium real output accounts for the relatively large decline in equilibrium total factor productivity.

Table 5.3 Effect of Inflation Reduction on Macroeconomic Stability Based on the Baseline Model[1, 2]

Table 5.3A Changes in the Standard Deviation of Selected Disequilibrium Variables

	5%	3%	1%
C	1.08	1.08	1.12
FA	0.98	1.07	1.16
INV	1.08	1.11	1.24
K	0.94	0.88	0.87
NETX	1.02	1.01	0.99
PCDOT	1.04	1.06	1.14
PDOT	1.05	1.08	1.16
R	1.05	1.06	1.17
RL	1.05	1.06	1.15
RN	1.02	1.01	1.13
RNL	1.02	0.99	1.07
RSL	1.05	1.07	1.18
U	1.08	1.18	1.34
W	1.01	1.03	0.94
Y	1.05	1.10	1.17
Z	1.00	0.93	0.87

Table 5.3B Changes in the Standard Deviation of Selected Equilibrium Variables

	5%	3%	1%
C.EQ	1.03	0.96	1.05
CC.EQ	1.01	0.95	1.03
FA.EQ	0.98	0.96	0.90
INV.EQ	1.04	1.00	1.17
K.EQ	1.00	0.99	0.95
RL.EQ	1.00	0.99	0.95
RN.EQ	0.98	0.96	0.90
RNL.EQ	0.98	0.95	0.89
U.EQ	1.00	0.99	0.96
W.EQ	0.99	0.95	0.95
Y.EQ	0.99	0.92	1.00
Z.EQ	1.00	0.99	0.94

1. The standard deviation for each variable is normalized to be one at the 7 percent inflation target level.

2. For each inflation target, the standard deviation for each variable over the period 1966-92 is further averaged across the 100 replications to produce a "grand standard deviation".

down to 3 percent. However, the volatility increases significantly when the target is reduced further to one percent. This phenomenon is closely linked to the higher forecast inflation gap at lower inflation targets. The model postulates that agents' expectations relate linearly to different horizons of actual inflation. This means agents concede no more credibility to monetary policy in lower inflation regimes than they do in higher inflation regimes. Moreover, as chapter 3 and earlier sections of this chapter explain, the model assigns only one-fifth of the total weight in the inflation-expectations process to the monetary authority's inflation target. Consequently, the monetary authority may have to react strongly to anticipated inflationary shocks in order to achieve its inflation target, in particular when the targets are low. A potential effect of this feature of the model is that inflation forecasts will tend to rise significantly in anticipation of inflationary shocks and fall significantly shortly after those shocks have materialized and the desired monetary policy is in place. Thus, this feature will tend to increase volatility of inflationary expectations in particular, and of the endogenous model variables in general.

The standard deviation for most variables in the disequilibrium model (table 5.3A) shows a similar pattern. Real consumption expenditures, financial assets, real investment expenditures, and the interest rates show a greater increase in volatility as the inflation target is reduced. Most of the other variables become only slightly volatile. In general, the interest rates become more stable as the inflation target falls from 5 percent to 3 percent, but less so when the inflation target falls further to 1 percent. A number of variables, including the capital stock, the real exchange rate and net exports become increasingly stable at lower inflation rates.

Unlike the disequilibrium model, variables in the equilibrium model appear to be consistently more stable at lower inflation rates. For most of the variables, volatility begins to fall at the 3 percent inflation target. There are a few of them, mainly equilibrium consumption expenditures, equilibrium net investment expenditures and equilibrium real output, which become more stable at moderate inflation targets (5 percent and 3 percent) but turn just as volatile at one percent inflation target as they are at the 7 percent target.

The analysis in this chapter shows that within the range of 1 percent to 7 percent inflation target, reducing the target reduces real output and raises the unemployment rate because the same inflation reduction (2 percent) requires progressively tighter monetary policy when the inflation target is already low. These policy-induced macroeconomic effects are strong in the short run but become very weak in the medium to long run. On the other hand, the policy appears to improve macroeconomic stability when the inflation targets are set within the range of 5 percent to 3 percent. However, moving the target lower to the neighbourhood of 1 percent makes many macroeconomic indicators more volatile in the short run because monetary policy becomes more aggressive.

The strongest arguments against low-inflation targeting in Canada have been couched in terms of inflexibility of labour market dynamics.[85] Therefore, chapter 6 introduces the assumption of downward nominal wage rigidity into the model in an attempt to investigate how inflexibility in the labour market influences the conclusions drawn in this chapter about macroeconomic effect of policy-induced inflation reduction.

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[85] See Fortin (1996), for example.

CHAPTER 6
THE MODEL WITH DOWNWARD NOMINAL WAGE RIGIDITY

Section 6.1 Channels of Transmission for Downward Nominal Wage Rigidity

At moderate to high inflation rates, businesses can reduce real wages either by freezing nominal wages or by allowing nominal wages to grow at a lower rate than the rate of inflation. However, when inflation is low, substantial reduction in real wages can be achieved only through nominal wage cuts. If workers oppose nominal wage cuts, or if employers dislike wage cuts because of potential adverse effect on workers' morale, the lack of avenue for the real wage to adjust downward can cause persistent high unemployment. Fortin (1996) argues that downward nominal wage rigidity contributed to Canada's persistent high unemployment rates in the first half of the 1990s.

If nominal wages cannot adjust downward in the event of negative aggregate demand shocks or negative productivity shocks, labour costs will exceed their market-clearing levels. The higher labour costs will, on one hand, directly reduce employment, and on the other hand, raise the rate of inflation and inflationary expectations as businesses pass on some of the higher costs to consumers. The effect on inflation is particularly important if monetary policy focuses on controlling inflation. In the case where monetary policy seeks to achieve a pre-set inflation target, the higher inflationary expectations will increase the forecast inflation gap - the difference between the inflation target and the forecast inflation (or expected inflation) for future periods. The size of the inflation gap will be proportional to the forecast inflation and inversely proportional to the inflation target. As monetary policy tightens to close the inflation gap, interest rates and the cost of capital will rise. The higher costs of capital motivate businesses to reduce investment spending, causing real output and employment to fall further. The output and employment losses may last longer if prolonged decline in investment expenditures reduces long-term growth in the stock of capital.

Downward nominal wage rigidity may also raise total labour income if the positive nominal wage effect outweighs the negative employment effect.[86] Higher labour income tends to raise the tax base, relax the fiscal budget constraint, and reduce the personal income tax rate. However, the recessionary effects discussed earlier increase net government transfers to the public, which tends to tighten the fiscal constraint and raise the income tax rate. The net effect on disposable income affects consumption expenditures, aggregate demand and hence real output and employment. Finally, the higher interest rates may have little net wealth effect as they simultaneously increase public debt and households' financial assets.

6.2 Empirical Evidence for Downward Nominal Wage Rigidity

John Maynard Keynes (1936) elaborated on the causes and consequences of downward nominal wage rigidity, and James Tobin (1972) stressed the economic importance of downward nominal wage rigidity in his 1971 presidential address to the American Economic Association. However, empirical work on this topic received close attention lately starting with a study by Akerlof, Dickens and Perry published in 1996. Subsequent studies have revealed that the number of wage settlements stipulating wage freezes (zero wage change) increase appreciably during low-inflation periods which, until the advent of formal inflation targeting by many industrialized countries in the late 1980s, typically coincided with economic recessions. It seems intuitive that businesses typically chose to freeze wages when unfavourable economic conditions made it necessary to cut wages.

Akerlof, Dickens and Perry (1996) analyse the Bureau of Labour Statistics data on union settlements for US private workers over the period 1970-94. They note that wage cuts were common only in the immediate aftermath of the 1981-82 recession when unemployment peaked above 10 percent, the highest level since the Great Depression. In 1982, 42 percent of new contracts had freezes and only 2 percent had wage cuts.

[86] The supply-side of the model is based on a Cobb Douglas production function with elasticity of demand for capital equal 0.34 and elasticity of demand for labour equal 0.66. Factor substitution effects in the model is likely to be small because the elasticity of substitution is unitary, and both labour costs and investment costs are rising.

However, the harsh realities of the 1981-82 period weakened the resistance to wage cuts, causing 15 percent of all wage settlements in 1983 to decline in the first year. Wage freezes accounted for only 22 percent of all wage settlements.[87] Excluding 1983 from the entire sample leaves only 1.7 percent of workers experiencing wage cuts in the first year of a contract.

Khan (1997) examines data from the US Panel Study of Income Dynamics (PSID) for evidence of downward nominal wage rigidity.[88] She estimates that about 9.4 percent of wage earners who would have received nominal wage cuts between 1970 and 1988 experienced wage freezes because of downward nominal wage rigidity.[89] She concludes that "wage earners receive nominal wage cuts less frequently than would be expected on the basis of the distribution of real wage changes." A study by Groshen and Schweitzer (1996) based on longitudinal data from the Federal Reserve Bank of Cleveland Community Salary Survey notes that wage changes involve two relative price changes – intra-occupational wage change which is employer specific, and employer-wide occupational wage change that affects broadly-defined labour markets.[90] The study concludes that inflation increases the range of both types of wage adjustments. In particular, low inflation (less than 4 percent) significantly reduces the range of occupational wage adjustments, and thereby deprives the economy of the "grease" that enables it to smoothly adjust to shocks.[91]

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[87] This observation is consistent with Bewley's recent survey discussed earlier in this chapter, which shows that both management and workers generally consider wage cut to be necessary only when businesses are under extreme duress - for example, when businesses face imminent bankruptcy.
[88] The PSID is a longitudinal database generated by interviewing the same individuals every year. Khan focussed his study on household heads because the PSID directly interviews them, and directs its full set of labour market questions only to them.
[89] She infers the distribution of percentage wage change in low-inflation periods from the distribution in high-inflation periods under the assumption that the notional distribution of percentage wage change around its median is invariant to the level of inflation.
[90] They argue that employer-specific wage adjustments are distortionary because they reflect intra-market variations in the speed of wage adjustments to inflation and forecasting errors. On the other hand, occupational wage changes include a higher concentration of inter-market relative price adjustments which facilitate normal adjustment of the labour market to structural changes.
[91] Groshen and Schweitzer assumed 1.5 percent productivity growth. Their data cover the period 1957-1992, and are drawn from the cities of Cleveland, Cincinnati and Pittsburgh.

Recent research based on Canadian data reveal labour-market characteristics that Tobin (1972), Akerlof et.al (1996) and others associate with downward nominal wage rigidity. In a study based on large Canadian wage settlements that do not include cost of living adjustment clauses (non-COLA wage settlements), Fortin (1996) observes significant differences in the distribution of wage changes between periods of low inflation and periods of moderate or high inflation.[92] Over the period 1986-1988 when the rate of inflation averaged 4.2 percent, the median wage change among the recorded 1,230 large Canadian non-COLA wage settlements was about 4 percent. Only 12 percent of settlements involved wage freezes. These figures contrast sharply with the period 1992-94 when 47 percent of the 1,149 large non-COLA wage settlements involved wage freezes. Inflation averaged 1.2 percent during this period, and the median wage change for the 1,149 settlements was around zero.[93]

Crawford and Harrison (1997) re-examine the Canadian microdata on wage settlements between 1978-96. They confirm earlier observation by Fortin (1996) that wage freezes are more frequent during low-inflation periods. However, they caution that this observation may not necessarily reflect downward nominal wage rigidity. They argue that small menu costs and uncertainty about inflation can substantially increase the density of nominal wage change at zero. They categorize wage freezes based on the *lifetime*, the *first year* and the *year-over-year* wage-change definitions.[94] They argue that the first-year definition does not adequately measure the overall wage growth in any given year because some multi-year contracts front-load wage freezes while others defer them to latter years. Their estimates based on the hazard function shows that the lifetime

[92] The wage settlements data measure the percentage change in the base wage rate in union agreements for bargaining units with at least 500 employees. The base wage is defined as the wage rate for the lowest-paid job category containing a significant number of employees. Crawford and Harrison (1997) note that the data coverage in recent years is approximately 55 percent of unionized employees and 20 percent of all paid non-agricultural employment in Canada. It includes only about 10 percent of paid employees in the private, non-agricultural sector.

[93] Over this period (1992-94), 47 percent of the settlements involved wage increases and only 6 percent involved wage cuts.

[94] The first year definition of wage freeze considers only contracts with zero wage change in the first year, even if there are wage changes in later years of the contract. The year-over-year definition considers all existing contracts, including new ones, that stipulate zero wage change in the year in question. The lifetime

definition of wage change produces no spike at zero.

The study also distinguishes between private-sector and public-sector wage settlements. It shows that during the first part of the 1990s, the public sector froze wages more frequently than the private sector under all three definitions of wage freezes. The authors attribute this difference between private sector and public sector wage settlements to the large number of wage restraint programs in the public sector. In general, the study suggests that Fortin's (1996) analysis based on the first-year definition of wage change overstates the importance of wage freezes in the base wage settlements data, and incorrectly attributes the phenomenon to downward nominal wage rigidity.

Simpson, Cameron and Hum (1998) extend Fortin's analysis on Canadian base wage settlements to address some of the issues raised in Crawford and Harrison (1997). They categorize the base wage settlement data into union- and non-union settlements, and private- and public-sector settlements, and apply the *first-year* and *lifetime* definitions for wage change to each category. They also analyze two other sources of Canadian microdata – the 1989-90 Labour Market Activity Survey (LMAS) longitudinal file and the 1993 Survey of Labour and Income Dynamics (SLID). The LMAS and SLID data include workers from both large and small employers, unionized and non-unionized. The authors confirm earlier observation by Fortin and others that the distribution of percentage base wage change is approximately normally distributed in periods of moderate to high inflation (1978-81, 1987-90) but truncated by a noticeable spike at zero percent in low-inflation periods (1983-86, 1993-95). The private sector as well as the pooled sample including both private and public sectors showed a remarkable spike at zero percent under both first-year and lifetime base wage change definitions. The LMAS and SLID data produced similar, though less dramatic, results.[95]

Fortin (1996) argues that downward nominal wage rigidity played an important role in

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definition of wage freeze considers only contracts with an average annual wage change of zero percent.

[95] The authors attribute the more diffuse spike at zero in the LMAS and SLID data to the "noisy nature of

Canada's experience with persistent high unemployment throughout the first half of the 1990s. In his view, the inflation-unemployment figures conformed to conventional predictions during the period 1990-92, but deviated considerably in the four years that followed. In his words, "*Previous accounts of the trade-off between inflation and unemployment in Canada held it that in a calm supply environment the annual inflation rate would continue to fall 1 percentage point per 2 point-years of excess unemployment above the NAIRU. ...The experience of 1990-92 initially confirmed this thumb rule: inflation fell by 3.5 points (from 5.0 to 1.5 per cent), while cumulative excess unemployment above 7.5 per cent amounted to 7.3 point-years. Over the period 1993 to 1996, with unemployment averaging 10.2 percent, the same Phillips-curve assumptions would have predicted a further decline of 5.5 points in inflation, to a deflation rate of 4 per cent. The puzzle is: why has this decrease not happened?*" Fortin (1996, p. 778). In his view, this observation about the Canadian Phillips curve resembles Tobin's (1972) and Akerlof, Dickens and Perry's (1996) description of the effects of downward nominal wage rigidity based on U.S data.

Recent studies have suggested a number of conjectures to explain the Canadian Phillips curve. Rose (1988), and Fortin (1989) suggest that changes to the unemployment insurance act, increase in payroll taxes, higher employment costs due to union power, and other developments during the 1980s may have raised the non-accelerating inflation rate of unemployment (NAIRU) between the 1980s and 1990s.[96] Fortin(1991), Poloz and Wilkinson(1992), and Jones(1995) suggest that persistent actual unemployment may have exerted diminishing effect on inflation over time (i.e. unemployment hysteresis). Rickettes and Rose(1995), and Fillion and Leonard(1997) argue that changes in monetary policy strategy between the 1980s and 1990s may have changed the process by which agents form expectations about inflation and other relevant variables. Finally, the observation by Fortin(1996), Simpson, Cameron and Hum(1998), and Crawford and Harrison (1997) that wage settlements have different dynamics in moderate- and high-

microdata, and the less precise measure of pay change."

[96] Fortin estimates that the NAIRU may have increased from 7.5 percent to over 9 percent during this

inflation periods than in low-inflation periods suggests that downward nominal wage rigidity may have shaped the Canadian output-inflation nexus in an important way.

Fortin (1997) uses a nested model to test for the above conjectures about the nature of the long-run unemployment-inflation relationship in Canada, and finds support for only two - a structural break for the period 1974-91, and nominal wage and price rigidities. The long-run Phillips curve estimated after introducing these restrictions had a slope of -1.72 percentage points when average nominal wage growth is above 4.0 percent, but only -0.67 percent when average nominal wage growth is below 4.0 percent. That is, the long-run Phillips curve becomes flatter at low inflation rates, so that each percentage-point permanent reduction in inflation requires a permanently higher unemployment rate.

Section 6.3 reviews the theoretical literature on downward nominal wage rigidity to put the empirical data discussed in this chapter into perspective. Section 6.4 incorporates the downward nominal wage rigidity assumption into the model discussed in chapters 3 to 5.

6.3 Sources of Downward Nominal Wage Rigidity: Review of the Theories

Proponents of the natural rate theory assume that real wages flexibly adjust to equilibrate the labour market, allowing the unemployment rate to gravitate towards the natural rate in the long run. According to this theory, the level of aggregate expenditures determines the wage- and price inflation consistent with the long-run equilibrium of the economy, and does not influence that equilibrium.[97] Consequently, the rate of inflation cannot influence long-run equilibrium levels of employment and output.

In the *General Theory of Employment, Money and Interest*, Keynes suggested a number of reasons why these neoclassical labour-market assumptions are unrealistic. First,

period.

[97] Classical economic theory associated full-employment equilibrium with constant nominal wage growth. New-Classical economists characterize full-employment equilibrium with nominal wages growing at the rate of productivity gain plus (expected) price inflation.

workers care about relative wages more than absolute wages. Therefore any change in nominal wages that alters relative wages will impact labour supply. Second, wage contracts are bargained in monetary terms and fixed for finite periods of time, making it impossible to cut nominal wages in decentralized, unregulated labour markets without impacting relative wages.[98] Third, nominal wage cut is unpopular because workers resist it, and employers worry about potential adverse effect on morale and productivity. Economists writing in the Keynesian tradition have expanded the sources of downward nominal wage rigidity to include the effects of implicit contracts, interdependence between productivity and wages, monopoly unions, and adjustment costs.

6.3.1 *The Implicit Contract Theory*

The implicit contract theory attempts to derive wage rigidity as the natural outcome of rational profit and welfare maximization. Implicit contracts are informal agreements between employers and workers regarding the terms of employment. According to Tobin (1972), wages and salary rates are insensitive to labour-market slackness partly because "*the employer makes some explicit or implicit commitments in putting a worker on the payroll in the first place.*[99] *The employee expects that his wages and terms of employment will steadily improve, certainly never retrogress. ... He expects such commitments in return for his own investments in the job; arrangements for residence, transportation, and personal life involve set-up costs which will be wasted if the job turns sour. ...There is not even an auction where workers and employers unbound by existing relationships and commitments meet and determine a market-clearing wage. ...[Rather,] Wage rates for existing employees set the standards for new employees.*"

Tobin verbally describes a model that assumes a heterogeneous labour market with non-

[98] On the contrary, a general rise in prices resulting from an increase in aggregate demand, for example, causes less distortions because it universally reduces real wages. Thus, the preference for price inflation over nominal wage cuts is based on efficiency and not on money illusion.

[99] In Tobin's view, monopoly power in large corporations and unions constitute another source of downward nominal wage rigidity.

linear relationship between money wage change and excess demand - unemployment retards money wages less than job vacancies accelerate them. The model assumes downward nominal wage rigidity by stipulating that wage change in each market has a non-negative floor that is invariant to the amount of excess supply. Demand shifts between heterogeneous labour markets cause some markets (not always the same ones) to be constrained by the floor. Businesses in constrained markets reduce employment and output. In general, the frequency of markets facing floor constraints varies inversely with the levels of aggregate demand and inflation.

Baily (1974), Gordon (1974), and Azeriadis (1975) formalize the implicit contract theory, and Harris and Holmstrom (1982), and Holmstrom (1983) further develop and extend it. Models based on the implicit contract theory have evolved along two closely related lines. The first, and formally more elegant, strand assume that employers and employees differ in terms of their attitude towards risk. The second strand is based on minimizing employee turnover costs. The risk-preference models assume that workers are risk averse and want to minimize income fluctuations as the firm encounters different phases of the business cycle. Workers prefer a guaranteed income based on a contract that combines a lower wage and job security[100] to an equivalent expected income based on a contract that combines a higher wage in high-demand periods and a lower wage (possibly layoffs) in low-demand periods. Businesses, on the other hand, are risk neutral; they are indifferent between offering either the risky contract or its certainty equivalent.[101] The turnover cost models emphasize costs to employers of voluntary employee turnover. These costs include search costs, screening expenses and investment in training. To avoid these costs, the employer offers employees "fair" treatment by providing attractive long-term contracts in exchange for long-term commitment from workers.[102]

[100] When layoffs are inevitable (as in the case of declining industries), the contract provides for enough severance pay to leave workers as well off at the time of layoff as they would be if they had kept their jobs.
[101] Businesses take more risks on income fluctuations than workers because entrepreneurs typically own more capital than workers, and can diversify better to reduce total risks. Moreover, entrepreneurship by itself, signifies a risk-taking attitude.
[102] Mitchell (1986, p. 56). Okun (1981chp. 2 and 3), provide a good exposition of this class of models.

Models based on the implicit contract theory predict downward nominal wage rigidity only when contracts are set in nominal terms. When contracts are set in real terms to protect purchasing power of workers, the models predict real wage rigidity; not nominal wage rigidity. The implicit contract theory also predicts unrealistic employment cycles because large severance payments cause businesses to hesitate laying off workers during recessions than during booms when jobs are easier to find. Consequently, the theory understates cyclical fluctuations in unemployment.[103] Bewley's (1999) survey of a number of U.S. businesses shows that employers find the assumptions of the implicit contract theory to be "too vague". For example, talks about mutual insurance agreements may raise difficult issues and draw attention to the possibilities that the firm might need to lay off workers.

6.3.2 *The Efficiency-wage Theory*

The efficiency-wage theory assumes that wage levels affect morale: Workers offer extra effort either out of gratitude for generous pay or as a means to protect their well-paid jobs. Major contributors to this theory include Solow (1979), Akerlof (1982), Akerlof and Yellen (1988, 1990) and Summers (1988). According to this theory, workers' marginal productivity depends not only on personal characteristics, skills, and technology, but also on the wage they are paid relative to what they consider to be a "fair wage".[104] Models based on the efficiency-wage theory emphasize moral hazard. As an alternative to costly or technically difficult supervision, employers may pay wage premiums to prevent shirking by workers. The wage premium discourages shirking by making it costly for the worker to lose the job. In general, the perceived "fair wage" varies with the degree of slackness in the labour market. However, the staggered nature of wage contracts in the macro economy will typically cause an employer's wage to deviate from the perceived

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[103] Attempts to address these problems, such as the introduction of asymmetric information between workers and employers, typically lead to more complex models and less realistic assumptions. Major contributions in this area include Grossman and Hart (1981, 1983), Green and Khan (1983) and Cooper (1983).

[104] Among other factors, the "fair wage" depends on the pay other workers receive at the same firm and at other firms, on past pay, and on general labour-market conditions.

"fair wage" if that employer cuts its nominal wage. Consequently, individual employers will be reluctant to cut wages, even in periods of falling demand.

Results from most of the recent surveys show that the efficiency-wage theory explains downward nominal wage rigidity better than most of the competing theories. For example, Bewley and Brainard (1993) discovered that businesses did not frequently cut pay when sales declined because of potential adverse effect on morale. Campbell and Kamlani (1995) concludes that businesses are reluctant to cut wages during recessions because they are afraid to lose their most productive workers "who, presumably, were receiving lower wages relative to productivity than their coworkers". Kahneman, Knetsch and Thaler (1986), and more recently Bewley (1999) reach similar conclusions. A notable departure from the predictions of the efficiency-wage theory, however, is the observation by most of these surveys that businesses invariably cut wages when faced with weak demand for two years or longer.

6.3.3 *The Adjustment Cost model*

Menu cost theory, originally developed to explain sluggish product price adjustment,[105] has been extended to explain downward nominal wage rigidity.[106] The theory attributes downward nominal wage rigidity to the cost of changing wages. If firms' profits are smooth functions of the wage rate, small deviations from the optimal wage will have little effect on profits. Even if the cost of adjustment is small, businesses may overlook minor deviations from the optimal wage until relatively large wage adjustments are necessary.

The adjustment cost theory is intuitively appealing because wage adjustments could be costly when they involve negotiating new wage contracts. However, Bewley (1999) notes in his survey of U.S firms that of all the businesses he studied, "no manager ... ever said that administrative or negotiation costs interfered with pay cutting".

[105] See Mankiw (1985), and Akerlof and Yellen (1985).
[106] Blanchard and Kiyotaki (1987), Akerlof and Yellen (1985b), Fischer (1977), and Taylor (1979,1990).

6.3.4 *The Monopoly Union Models*

The Monopoly union theory attributes downward nominal wage rigidity to the bargaining power of large labour unions that represent workers' interests in contract negotiations. The monopoly union theory generally assumes that unions choose the wage they want for their members, and accept the employment level consistent with the firm's labour demand schedule based on that wage.[107] Tobin (1972, p. 14) attributes post-war wage and price increases in the face of mass unemployment to emerging labour unions who, under the protection of new federal legislation, changed their objectives in favor of wages at the expense of employment. Akerlof, Dickens and Perry (1996) construct and calibrate a wage model that determine the relative bargaining power of unions and employers based on the degree of slackness in the labour market, the level of demand for firms' products, the value of workers' leisure time, and the average (occupational) wage in the labour market.[108]

The monopoly union theory is limited by the fact that rational union leaders may not narrowly focus on preventing wage cuts and neglect employment risks (layoffs) for some current members.[109] To address these issues, researchers have extended the theory to include a class of models that feature seniority rights and insider-outsider relationships. The seniority rights models assumes that unions are controlled by members with highest seniority, whose jobs are so well protected by seniority privileges that they do not feel threatened by layoffs except in very acute low-demand situations.[110] The insider-outsider models focus on how potential competition from unemployed workers affects the wage rate.[111]

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[107] See Reynolds (1981), Hart (1982) and McDonald and Solow (1985).

[108] Firm's in the model operate in monopolistic competitive markets and face heterogenous demand and supply shocks. The model assumes downward nominal wage rigidity based on an autoregressive scheme, and allows firms to pay the notional wage less a factor of the negative demand shock only if a firm experiences two consecutive losses.

[109] See for example, Hahn (1978) and Negishi (1979).

[110] See Shister (1943) and Oswald (1986).

Bewley (1999) notes that the monopoly union theory involves a number of unrealistic assumptions. First, they attribute too much power to unions by assuming that unions unilaterally set the wage rate. As Mitchell (1972) notes, union leaders face formidable employer bargaining power in determining the wage rate. Second, the theory applies to a small fraction of the labour force because only a few U.S. and Canadian firms are unionized. Third, opposition to pay cuts does not necessary come from union leaders or the work force. Earlier discussion in this chapter shows that employers have little incentive to cut wages because of potential adverse effect on workers' morale and productivity.

6.4 Do Existing Theoretical Models Adequately Explain Downward Nominal Wage Rigidity?

Bewley's survey of U.S. firms (published in 1999) notes that neither workers nor employers desire to cut wages during recessions.[112] In 69% of the businesses he surveyed, management thought cutting the pay of existing employees would prompt reactions that could cost the firm more money than the pay cut would save. Employers in 42% of the businesses thought pay cuts would hurt productivity. Forty-one percent thought pay cuts would increase turnover. Other reasons employers would not cut wages include fear of sabotage, resistance from unions, increased unionization, and unwillingness of managers to cut their own pay. However, no more than 5 percent of all employers interviewed cited these reasons as major concerns. Bewley concludes that the only reasonable theory of downward nominal wage rigidity is one based on the adversely affect of wage cuts on workers' morale and productivity.[113]

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[111] See Lindbeck and Snower (1988a, b), and Layard, Nickell and Jackman (1991).
[112] Bewley (1999) surveyed a number of businesses in the United States between 1992 and 1994 to determine why wages do not fall during recessions. He interviewed the leaders of 13 temporary labour businesses, 235 active non-labour businesses, and 4 failed businesses. His sample of businesses were mostly from Connecticut and a few other states on the eastern coast of the United States.
[113] Bewley (1999, p.423).

Kahneman, Knetsch and Thaler (1986) surveyed households from the Toronto and Vancouver metropolitan areas to determine public perception about fairness on a number of hypothetical business pricing, wage setting and other human resource management decisions. The study shows that most people think wage cuts are unfair except in extreme cases where businesses face imminent bankruptcy. The study also revealed some evidence of money illusion. Respondents were more hostile to nominal wage cuts than equivalent reduction in real wage caused by higher inflation.[114] The authors conclude that wages tend to be relatively insensitive to excess supply in the labour market because businesses are reluctant to exploit short-term fluctuations of demand for fear of being perceived by workers as unfair.[115]

The empirical data show that individual theories explain only a limited aspect of the complex mechanisms associated with downward nominal wage rigidity. Moreover, some theories make unrealistic assumptions while others logically lead to unrealistic predictions. The lack of a comprehensive and coherent theory to explain downward nominal wage rigidity has led an increasing number of empirical researchers to directly estimate the probability distribution of nominal wage change. However, the *censored* nature of this distribution during low-inflation periods requires that any empirical evaluation of downward nominal wage rigidity be based on some counterfactual distribution of nominal wage change. The simplest approach is to use the shape of the observed distribution in years of relatively high inflation as proxy for low-inflation periods.[116] However, this approach has limitations because it does not allow the shape of the distribution to change over time. Card and Hyslop(1996) address this problem by assuming a symmetric distribution about the median wage change and allowing the entire distribution to change over time in response to changes in the rate of inflation. Simpson, Cameron and Hum (1999) allows for heteroscedasticity in its censored regression model

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[114] Sixty-two percent considered it unfair for a company making a small profit to cut wages by 7 percent if inflation were zero. On the other hand, only 22 percent of respondents thought a five-percent increase in nominal wages would be unfair if inflation is at 12 percent.

[115] In their view, differences in pay, both within and among occupations, is insufficient to eliminate the excess demand for individuals considered most valuable, and the excess supply of those considered most dispensable.

of wages on unemployment and inflation, which allows the shape of the wage distribution to change over time. However, the statistical tests generally rejected heteroscedasticity in the wage settlements data up to 1995.

Donald, Green and Paarsch(1995), Green and Paarsch(1996), and Crawford and Harrison(1997) estimate the notional distribution of nominal wage change using the hazard function. The hazard function is the conditional probability of observing a nominal wage change within any specified interval. Two important characteristics make the hazard function useful in specifying the notional probability distribution of nominal wage change. First, it allows covariates to be introduced into the estimation, thereby making the entire density for nominal wage change respond to changes in the relevant economic variables. Secondly, the hazard function is a transformation of the density function and therefore allows the latter to be recovered from standard estimation of the hazard function.

The thesis adopts the method that estimates the notional distribution for percentage nominal wage change. However, unlike other studies that use the hazard function to incorporate covariates into the distribution, the thesis bases the distribution of the nominal wage change on the normal density function and incorporates covariates by integrating the wage model into the larger macroeconomic model. This approach allows the entire density to respond to dynamics in the relevant variables from the rest of the model.

Based on empirical studies discussed earlier in this chapter, the thesis does not investigate whether nominal wages are downwardly rigid in Canada. Rather, it assumes recent studies have adequately established the existence of the phenomenon. The rest of the chapter proceeds to study how this phenomenon affects real output and employment at different inflation target levels. In the rest of the thesis, the *Baseline Model* refers to the version of the model that does not include the downward nominal wage rigidity

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[116] Khan (1997), for example.

assumption[117], and the *Downward nominal wage rigidity Model* refers to the version that incorporates the downward nominal wage rigidity assumption.

6.5 Incorporating the Downward nominal wage rigidity Assumption into the Model

In the baseline model, households supply labour elastically.[118] Therefore, the marginal revenue product of labour determines the equilibrium nominal wage rate. As the model adjusts to shocks and other sources of dynamics in the short-run, the short-run (disequilibrium) nominal wage responds symmetrically to changes in product prices and labour productivity. This section introduces downward nominal wage rigidity into the model by partially reversing any potential short-term decline in nominal wages. Specifically, the model calculates an index for downward nominal wage rigidity pressure (nrp_t) for each period t, and adjusts the short-run (disequilibrium) relative wage equation accordingly. Equation (6.1)-(6.5) model the downward nominal wage rigidity assumption based on the normal density function. The subsequent paragraphs define the variables and explain each equation in detail.

$$pr\left(wch_{it}\right)=\frac{1}{wsd*\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{1}{wsd}\right)^{2}\left(wch_{it}-avgwch_{t}\right)^{2}\right] \tag{6.1}$$

$$avgwch_{t}=100*\left(w_{t}-w_{t-1}\right)/w_{t-1}+pdot_{t}+qdot_{t} \tag{6.2}$$

$$wct_{t}^{e}=\sum_{i=m}^{0}pr(wch_{it})*wch_{it} \tag{6.3}$$

$$nrp_{t}=wct_{t}^{e}*w_{t-1}/100 \tag{6.4}$$

$$w_{t}=w.eq_{t}+h_{t}(\cdot)+wadj_{t}-nrp_{t} \tag{6.5}$$

Equation (6.1) states the assumption that the percentage nominal wage change (***wch***) is normally distributed with mean ***avgwch*** and standard deviation ***wsd***.[119] Equation (6.2)

[117] The model discussed in chapters 3 and 4, and simulated in chapter 5.
[118] This is true for both the equilibrium model and the disequilibrium model.
[119] Empirical research discussed earlier in this chapter shows that the historical data on base-rate settlements

calculates the mean percentage wage change (*avgwch)* based on the model's solution for aggregate percentage nominal wage change. *W* represents the relative wage in the disequilibrium model, *pdot* is the rate of inflation in the factor-cost price (i.e. trend inflation), and *qdot* is the growth rate of labour productivity. The model solves for *pdot* endogenously but sets *qdot* exogenously to 1.3 percent.[120] The model exogenously set *wsd* to 4.35 percent based on earlier empirical work discussed in this chapter.

Equation (6.3) calculates the average (probability-weighted) nominal wage cut (wct^e) in percentage points that would occur each period based on equations (6.1) and (6.2). $Pr(wch_{it})$ is the probability that a nominal wage change of magnitude wch_i occurs in period t. The relevant range of wage cuts, *[m, 0]*, is determined outside the model using the normal density function with standard deviation 4.35 and values of *avgwch* from -20 to 20.[121] Appendix 6 explains how this range was determined. Equation (6.4) uses the expected value of nominal wage cut (wct^e) from equation (6.3) to calculate the downward nominal wage rigidity index (*nrp*). The downward nominal wage rigidity index *nrp* is the expected value of nominal wage cuts expressed in the same units as the model's relative wage. It represents the counterfactual cyclical average wage cut. Nrp cannot exceed zero because wct^e is based on only nominal wage cuts (or negative nominal wage changes).

Equation (6.5) summarizes the disequilibrium model's relative wage equation modified to include the downward nominal wage rigidity assumption. The disequilibrium relative wage in each period (w_t) depends on four factors: w.eq, h(.), wadj and nrp. *W.eq* is the relative wage from the equilibrium model; h(.) represents responses of the disequilibrium relative wage to fluctuations in other variables based on structural relationships in the

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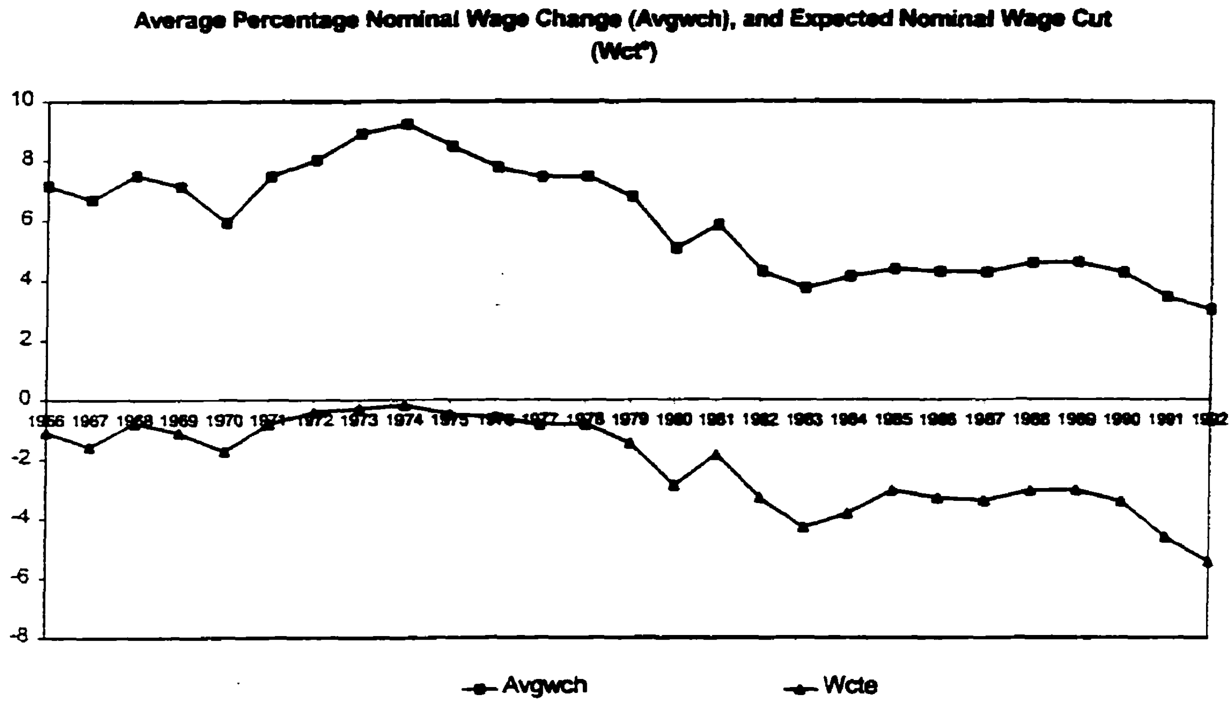
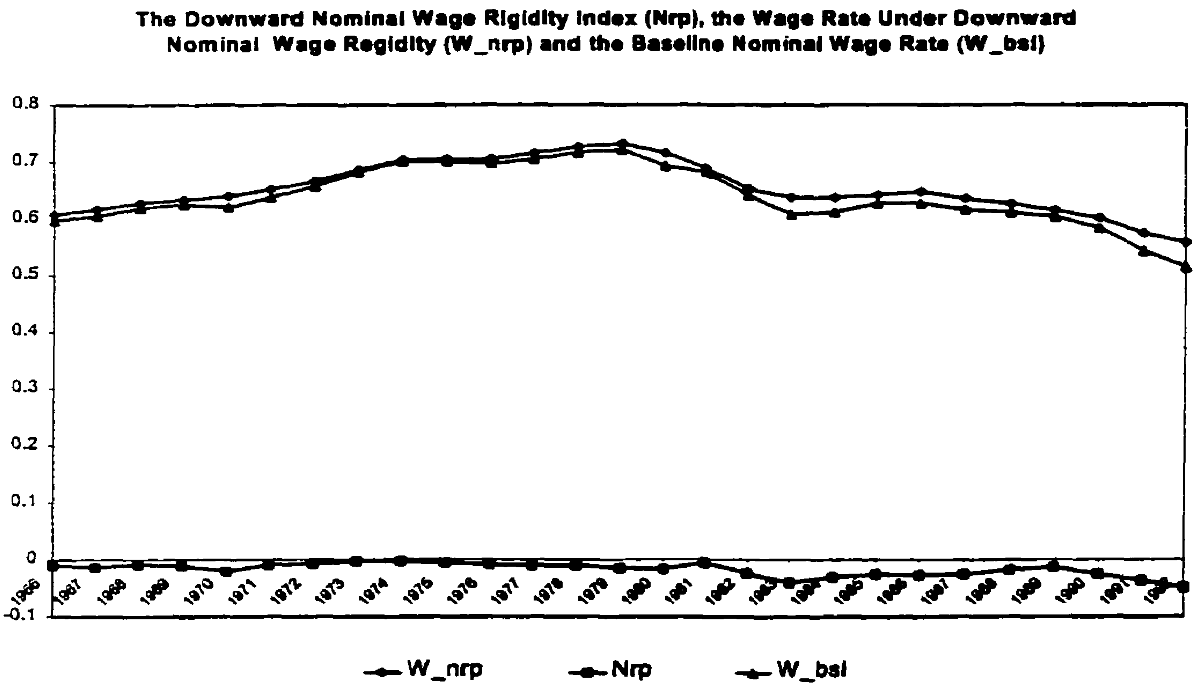
is approximately normally distributed in periods of moderate to high inflation. For example Simpson, Cameron and Hum(1998) show that during the period 1978-1981 when the rate of inflation averaged 10 percent, the distribution of percentage changes in base-rate settlements was approximately normally distributed with a mean of 9.94 percent and a standard deviation of 4.35 percent.

[120] Chapter 3 defines and explains pdot in detail. CPAM sets the annual growth rate of labour productivity to 1.3 percent.

[121] The percentage change in the base wage rate shown in most of the empirical studies quoted in this paper

Fig. 6.2: Deterministic Solution for Variables in the Downward Nominal Wage Rigidity Model





fall within this range.

model; wadj represents changes in the disequilibrium relative wage that result from attempt by workers to catch up with current and expected future inflation, and by businesses to adjust to changes in product price and labour productivity. *Nrp* is the downward nominal wage rigidity index calculated from equation (6.4). Fig. 6.2 charts the model's deterministic solution for the downward nominal wage rigidity variables defined in equations (6.2-6.5) when the inflation target is set at 4 percent, and compares the wage rate under the downward nominal wage rigidity assumption (W_nrp) with its counterpart in the baseline model (W_bsl).

6.6 Short-Term Macroeconomic Effects of Inflation Reduction, with and without the Downward Nominal Wage Rigidity Assumption

This section compares results from stochastic simulations based on versions of the model, with and without the downward nominal wage rigidity assumption. Each version of the model is simulated for four inflation targets - one percent, three percent, five percent and seven percent. The simulation at each inflation target involves 100 replications of history over the period 1960-95. The model simulates different shocks for each of the 100 replications. It also simulates different shocks for each period within a replication. However, it repeats the same set of shocks for all the four inflation targets in each version of the model. Therefore differences in the solution at each inflation target exclusively reflect the effect of the downward nominal wage rigidity assumption.

For each inflation target, the average and standard deviation for the period 1966-92 are further averaged over the 100 replications to produce a '*grand average*' and a "*grand standard deviation*" for each model variable.[122] In subsequent discussion, the values and standard deviation for each variable refer to these *grand averages* and *grand standard deviations* respectively.

[122] See footnote no. 9.

Table 6.1 HOW THE NOMINAL WAGE INDEX AFFECTS THE DISEQUILIBRIUM RELATIVE WAGE AND THE DISEQUILIBRIUM WAGE GAP (W-W.EQ)

	Baseline Model				Nominal Wage Rigidity Model			
INFLATION TARGET	7%	5%	3%	1%	7%	5%	3%	1%
PDOT (%)	6.93	5.14	3.21	1.26	7.21	5.20	3.26	1.32
AVGWCH					8.20	6.55	5.02	3.45
WCT^e					-1.68	-2.28	-3.08	-4.43
NRP					-0.011	-0.014	-0.019	-0.027
NRP Index (7% = 1.0)+					1.00	1.34	1.79	2.54
W	0.620	0.612	0.604	0.589	0.629	0.624	0.620	0.613
W.EQ	0.620	0.618	0.616	0.612	0.622	0.620	0.618	0.614
DISEQUILIBRIUM WAGE GAP	0.001	-0.921	-1.981	-3.896	1.207	0.764	0.388	-0.249
PCDOTE (%)	7.137	5.371	3.545	1.704	7.270	5.569	3.792	2.017
FORECAST INFLATION GAP	0.137	0.371	0.545	0.704	0.270	0.569	0.792	1.017

+ Normalized to be one when the inflation target is set at 7 percent.

1. The disequilibrium wage gap is the percentage deviation of the disequilibrium relative wage from its equilibrium counterpart (i.e. 100*(w/w.eq-1)).

2. The forecast inflation gap is the difference between the two-year ahead expected inflation in the consumer price index (pcdote) and the inflation target (pdottar).

Table 6.1 compares the relative wage at different inflation targets, with and without the downward nominal wage rigidity assumption. *W* is the short-term (disequilibrium) relative wage and *w.eq* is the medium- to long-term (equilibrium) relative wage. *Wgap* is the disequilibrium relative wage gap; it is the percentage *excess* disequilibrium relative wage (i.e. 100*(*w/w.eq-1*)).

The two models differ in at least three important ways with respect to the disequilibrium relative wage. First, the downward nominal wage rigidity model produces higher short-term relative wage than the baseline model at all four inflation targets. The downward nominal wage rigidity assumption involves adding the negative of the downward nominal wage rigidity index, *nrp*, to the disequilibrium relative wage equation to produce the counterfactual disequilibrium relative wage. Since *nrp* is negative at all four inflation targets, the disequilibrium relative wage under the downward nominal wage rigidity assumption is higher than its counterpart from the baseline model. When the inflation target is set at 7 percent, the downward nominal wage rigidity model produces a disequilibrium relative wage of 0.63; the corresponding figure from the baseline model is 0.62. When the inflation target is reduced to one percent, the disequilibrium relative wage falls to 0.61 and 0.59 respectively for the two models.

Second, the disequilibrium relative wage gap is generally higher at high inflation targets, and falls as the inflation target declines. Thus, the disequilibrium relative wage falls as the inflation target declines. As section 6.1 explains, high inflation produces an avenue for the relative wage to adjust automatically. However, such automatic adjustment is limited at low inflation rates, and businesses tend to resort to nominal wage cuts to reduce the relative wage. The baseline model produces non-positive relative wage gaps for all but one of the inflation targets. When the inflation target is set at 7 percent, the gap is zero, which means the disequilibrium relative wage coincides with the equilibrium relative wage. When the inflation target is set at one percent, the gap falls to negative 3.9 percent, which means the disequilibrium relative wage is approximately 4 percent below the equilibrium relative wage. The downward nominal wage rigidity model produces positive relative wage gap for inflation targets 3 percent and higher. At 7 percent inflation target, the disequilibrium relative wage is 1.2 percent higher than the equilibrium relative wage. When the inflation target is reduced to one percent, the disequilibrium relative wage falls 0.3 percent below the equilibrium relative wage.

Third, the downward nominal wage rigidity model produces higher disequilibrium relative wage gaps at all four inflation targets. However, the baseline model and the downward nominal wage rigidity model produce identical equilibrium relative wage at each inflation target since the downward nominal wage rigidity assumption does not directly affect the equilibrium relative wage. Therefore, the differences between the disequilibrium relative wage gap from the two models exclusively reflect differences in the disequilibrium relative wage. Thus, the higher disequilibrium relative wage in the downward nominal wage rigidity model translates into higher disequilibrium relative wage gap at all four inflation targets.

Finally, the downward nominal wage rigidity model to produce higher forecast inflation gap than the baseline model at all inflation target levels. This outcome results directly from the fact that the relative wage in the downward nominal wage rigidity model is sticky downward and tends to exceed the relative wage in the baseline model at inflation target levels studied. As chapter 5 explains, monetary policy reacts proportionately to the two-year forecast inflation gap. Therefore, monetary policy will tend to respond more vigorously in the case of downward nominal wage rigidity than in the baseline model at all inflation levels. Besides, as observed in chapter 5 with the baseline model, the forecast inflation gap in the downward nominal wage rigidity model rises as the inflation target falls. Consequently, monetary policy will react more vigorously at lower inflation targets than at higher inflation targets.

These four observations set the downward nominal wage rigidity model up to produce larger macroeconomic effects from inflation reduction than the baseline model, particularly at low inflation targets. The rest of section 6.3 and section 6.4 discuss how the differences in the disequilibrium relative wage and the disequilibrium relative wage gap due to the downward nominal wage rigidity assumption ultimately affect key macroeconomic variables at different inflation targets. As in tables 6.1 and 6.2, the figures in table 6.3 represent the *grand averages* described in the first two paragraphs of section 6.3. The model assumes that each inflation regime is permanent. Therefore table 6.3 estimates the *average* effect of inflation reduction over the period 1966-92. The thesis describes changes in the disequilibrium model as short-term in nature, and changes in the equilibrium model as medium- to long-term in nature.

6.6.1 Effect of Downward nominal wage rigidity Assumption when Inflation Target is Reduced from 7 Percent to Five Percent

Table 6.2 shows that when the inflation target is reduced from 7 percent to 5 percent, inflation expectations fall from 7.1 percent to 5.4 percent in the baseline model, and from 7.3 percent to 5.6 percent in the downward nominal wage rigidity model. Although the lower inflation target causes inflationary expectations to fall, it nevertheless, raises the forecast inflation gap due to imperfect policy credibility and structural rigidities, including downward nominal wage rigidity in the case of the downward nominal wage rigidity model.[123] The extent to which the inflation level affects the forecast inflation gap depends on how strong the inflation target influences agents' inflation expectations. This in turn depends on how agents perceive the policy to be credible and the extent to which structural rigidities impede smooth adjustment of relative prices. The expectations formation process in the model assigns about 20 percent weight to the inflation target.[124]

[123] The forecast inflation gap is the amount in percentage points by which expected inflation exceeds the inflation target.

[124] The small weight on the inflation target in the inflation expectations equation reflects a bias against policy credibility. Such a bias is expected to characterize the first few years following the introduction of low inflation targets. It also reflects the fact that the thesis focuses more on the costs than the benefits of inflation reduction. In CPAM, the inflation target receives a weight of 10 percent in agents expectations formation.

Table 6.2 Short-Term Macroeconomic Effects of Inflation Reduction, with and without the Downward Nominal Wage Rigidity Assumption

	Baseline Model			Nominal Wage Rigidity Model		
	7%-5%	5%-3%	3%-1%	7%-5%	5%-3%	3%-1%
C	-2.092	-2.377	-3.486	-2.254	-2.641	-3.025
FA	1.469	1.406	1.062	1.315	1.647	1.139
GB	1.372	1.535	2.065	1.363	1.672	2.565
GTR	2.050	2.403	3.647	2.164	2.663	4.675
INV	-0.943	-1.777	-3.185	-1.218	-2.092	-3.346
K	-0.146	-0.737	-1.062	-0.188	-0.843	-1.282
NETX	-3.304	-5.126	-6.371	-3.864	-7.888	-9.040
NFA	-4.204	-5.734	-6.193	-5.109	-7.746	-7.418
NRP	na	na	na	1.340	1.787	2.265
PCDOTE+	0.371	0.545	0.704	0.569	0.792	1.017
PDOTE+	0.285	0.453	0.615	0.515	0.731	0.950
PCDOT+	0.151	0.238	0.277	0.242	0.259	0.379
PDOT+	0.141	0.213	0.259	0.201	0.262	0.315
R	0.489	0.673	1.011	0.607	0.917	1.272
RL	0.062	0.058	0.247	0.050	0.120	0.585
RN	-1.481	-1.114	-0.858	-1.170	-0.899	-0.721
RNL	-1.928	-1.745	-1.576	-1.759	-1.517	-1.347
RSL	0.382	0.546	0.686	0.539	0.763	0.799
TD	0.087	0.085	0.214	0.104	0.103	0.235
TFP	-0.980	-0.927	-1.495	-0.818	-0.825	-1.355
U	0.324	0.458	0.539	0.379	0.584	0.608
W	-1.270	-1.449	-2.477	-0.812	-0.647	-1.219
Y	-1.239	-1.484	-2.290	-1.349	-1.940	-2.699
YD	-1.030	-1.192	-2.137	-0.794	-0.716	-1.258
YLAB	-1.611	-1.896	-3.053	-1.346	-1.376	-1.892
Z	-0.367	-0.297	-1.473	-0.392	-0.436	-1.674

+ Expected inflation (pcdote), inflation in the producer price index (pdot) and inflation in the consumer price index (pcdot) measure deviations in percentage points from the inflation target.

Table 6.2 shows that the lower inflation target reduces the disequilibrium relative wage by 1.3 percent in the baseline model and by 0.8 percent in the downward nominal wage rigidity model. It also reduces the disequilibrium relative wage gap from zero to -0.9 percent in the baseline model, and from 1.2 percent to 0.76 percent in the downward nominal wage rigidity model. The higher relative wage and relative wage gap in the downward nominal wage rigidity model contribute to the higher inflationary pressures and thereby raise the forecast inflation gap further. On the other hand, the negative relative wage gap in the baseline model reduces pressure on the forecast inflation gap. The net effect of these forces creates a forecast inflation gap of 0.4 percent in the baseline model, and 0.6 percent in the downward nominal wage rigidity model.

Although the lower inflationary expectations cause long-term nominal rates to fall by 1.8 percentage points in the downward nominal wage rigidity model, the tighter monetary policy due to the larger forecast inflation gap raises the slope of the yield curve by 54 basis points. In the baseline model, long-term nominal interest rates fall by 1.9 percentage points and the slope of the yield curve rises by 38 basis points. Short-term real interest rates rise by 61 basis points in the downward nominal wage rigidity model compared with 49 basis points in the baseline model. The higher short-term borrowing costs reduce net investment expenditures by 1.2 percent and the capital stock by 0.19 percent in the downward nominal wage rigidity model compared with 0.9 percent and 0.15 percent respectively in the baseline model. The higher short-term interest rates also combine with the lower domestic inflation rates to appreciate the dollar by 0.4 percent in both models, causing net exports to fall by 3.3 percent in the baseline model and 3.9 percent in the downward nominal wage rigidity model.

The relative wage falls by 1.3 percent in the baseline model, but by only 0.8 percent in the downward nominal wage rigidity model partly because nominal wages are sticky downward, and partly because a larger decline in unemployment keeps total factor productivity high.[125] The lower relative wage tends to reduce labour income in both models. In the case of the downward nominal wage rigidity model, the 0.8 percent disequilibrium wage gap tends to reduce employment and labour income further. However, the –0.9 percent disequilibrium wage gap in the baseline model tends to raise short-term employment and labour income. Overall, labour income falls by 1.6 percent in the baseline model and by 1.4 percent in the downward nominal wage rigidity model. The lower labour income and higher interest costs contribute to the 2.1 percent and 2.3 percent decline in consumption expenditures in the baseline model and downward nominal wage rigidity model respectively.

The decline in consumption expenditures, investment spending and net exports combine to reduce aggregate demand relative to the output level consistent with the capital stock and employment rate. Consequently, total factor productivity falls by 1.0 percent in the baseline model contributing to the 1.2 percent decline in the relative wage. The lower aggregate demand causes real output to fall by 1.2 percent and the unemployment rate to rise by 0.3 percentage points. In the downward nominal wage rigidity model, total factor productivity falls by only 0.8 percent because of the larger increase in the unemployment rate. Therefore, the relative wage falls by only 0.8 percent. However, the larger decline in consumption and investment expenditures due to higher interest rates cause real output in this model to fall by 1.4 percent compared with 1.2 percent in the baseline model.

The lower aggregate demand and output levels reduce the tax base in both models. On the other hand, the higher unemployment rates raise government net transfers to the public by 2.1 percent in the baseline model and by 2.2 percent in the downward nominal wage rigidity model. In effect, the fiscal budget constraint tightens, necessitating a 0.1 percent increase in income tax rates in both models. The higher income tax rates combine with the lower labour income to reduce disposable income by 1.0 percent in the baseline model and by 0.8 percent in the downward nominal wage rigidity model. The lower disposable income and the higher interest rates account for the decline in real consumption

[125] For any level of output, a higher unemployment rate means higher labour productivity.

expenditures discussed earlier in this section.

6.6.2 Effect of Downward nominal wage rigidity Assumption when Inflation Target is Reduced from Five Percent to Three Percent

Reducing the inflation target from 5 percent to 3 percent reduces the disequilibrium relative wage gap from -0.9 percent to -2.0 percent in the baseline model, and from 0.8 percent to 0.4 percent in the downward nominal wage rigidity model. The relative wage falls by 1.5 percent in the baseline model but by only half as much in the downward nominal wage rigidity model. The higher relative wage and the positive relative wage gap unambiguously raise inflationary pressures in the downward nominal wage rigidity model and cause the forecast inflation gap to rise from 0.6 percentage points to 0.8 percentage points. In the baseline model, the negative relative wage gap dampens inflationary pressures, causing the forecast inflation gap to rise from 0.4 percentage points to just over 0.5 percentage points.

The higher forecast inflation gap in the downward nominal wage rigidity model causes monetary policy to tighten more, raising the slope of the yield by 76 basis points compared to 55 basis points in the baseline model. Short-term real interest rates rise 92 basis points in the downward nominal wage rigidity model, causing net investment expenditures and the capital stock to fall by 2.1 percent and 0.8 percent respectively. In the baseline model, the 67 basis points increase in real short-term interest rates reduce net investment expenditures by 1.8 percent and the capital stock by 0.7 percent. The negative relative wage gap in the baseline model produces a moderating effect on the unemployment rate, causing it to rise by less than 0.5 percentage points compared with 0.6 percentage points in the downward nominal wage rigidity model. in both models The higher unemployment rate combines with the lower relative wage to reduce labour income by 1.9 percent in the baseline model, contributing to the 1.0 percent decline in disposable income and 2.4 percent decline in real consumption expenditures. In the downward nominal wage rigidity model, labour income and real consumption expenditures fall by 1.4 percent and 2.6 percent respectively.

The higher interest rates also raise financial assets by 1.4 percent in the baseline model and by 1.7 percent in the downward nominal wage rigidity model, producing wealth effects that tend to raise consumption expenditures. The higher interest rates also combine with over 2.4 percent increase in net government transfer to the public in both models to raise the government debt-to-GDP ratio by 1.5 percent in the baseline model and by 1.7 percent in the downward nominal wage rigidity model. The higher government debt burden and lower tax base tighten the fiscal constraint causing income tax rates to rise by just about a percentage point in both models.

The lower aggregate demand produces *recession* and *capital stock effects* that are stronger but qualitatively similar to the case where the inflation target is reduced from 7 percent to 5 percent. Real output falls by 1.5 percent in the baseline model, and by 1.9 percent in the downward nominal wage rigidity model.

6.6.3 Effect of Downward Nominal Wage Rigidity Assumption when Inflation Target is Reduced from Three Percent to One Percent

Reducing the inflation target from 3 percent to 1 percent produces the strongest macroeconomic effects among the three cases presented in table 6.3. Although actual inflation rates fall by over 1.6 percentage points in the downward nominal wage rigidity model, the relatively large increase in the downward nominal wage rigidity index allows the relative wage to fall by only 1.2 percent compared with 2.5 percent in the baseline model. The larger decline in the relative wage in the baseline model causes the disequilibrium wage gap to drop form -2.0 percent to -3.9 percent compared with a drop from 0.4 percent to only -0.3 percent in the downward nominal wage rigidity model. The negative disequilibrium wage gaps tend to reduce inflationary pressures and encourage higher employment rates in both models. However, inflationary expectations remain high relative to the target rate because monetary policy is only partly credible and agents' decisions adjust sluggishly.[126] Agents in the baseline model expect inflation in the consumer price index to average 1.7 percent; which imply a forecast inflation gap of 0.7 percent. In the downward nominal wage rigidity model, agents expect inflation in the consumer price index to average 2.0 percent, which imply a 1.0 percent forecast inflation gap.

The relatively tight monetary policy required to keep inflation close to target raises the slope of the yield curve by 69 basis points in the baseline model and by 80 basis points in the downward nominal wage rigidity model. Short-term real interest rates rise by a percentage point in the baseline model and by 1.3 percentage points in the downward nominal wage rigidity model. The higher interest rates reduce net investment expenditures by 3.2 percent in the baseline model and by 3.5 percent in the downward nominal wage rigidity model, causing the capital stock to fall by 1.1 percent and 1.3 percent respectively. The lower inflation rates and higher interest rates appreciate the dollar by 1.4 percent in the baseline model and by 1.7 percent in the downward nominal wage rigidity model, reducing net exports by 6.4 percent and 9.0 percent respectively in the two models.

Total factor productivity falls more steeply in both models, particularly in the baseline model, signifying a greater decline in aggregate demand relative to the stock of capital and the employment rate at the low inflation target. Consequently, the relative wage in both models falls by twice as much as the case where the inflation target is reduced from 5 percent to 3 percent. The relative wage in the downward nominal wage rigidity model is 3.3 percent higher than its counterpart in the baseline model; this tends to raise labour income in the downward nominal wage rigidity model relative to the baseline model.

[126] Although reducing the inflation target raises the forecast inflation gap in both models, it nevertheless, reduces inflationary expectations. In the case of the downward nominal wage rigidity model, for example, the forecast inflation gap at 3 percent and 1 percent inflation targets are 0.8 percent and 1.0 percent respectively. These imply inflationary expectations of 3.8 percent and 2.0 percent respectively.

However, the unemployment rate is about one percentage point higher in the downward nominal wage rigidity model than in the baseline model; this tends to reduce labour income in the downward nominal wage rigidity model relative to the baseline model. The two forces combine to reduce labour income by 3.1 percent in the baseline model compared with only 1.9 percent in the downward nominal wage rigidity model, and account for a greater part of the 2.1 percent and 1.3 percent decline in disposable incomes in the respective models. Real consumption expenditures fall by 3.5 percent in the baseline model, almost 0.3 percentage points more than its counterpart in the downward nominal wage rigidity model. The lower aggregate demand reduces real output by 2.3 percent in the baseline model and by 2.7 percent in the downward nominal wage rigidity model, causing the unemployment rate to rise by 0.5 percent and 0.6 percent respectively.

The discussion in this section suggests that when workers resist nominal wage cuts, inflation reduction reduces real output and employment on short-term basis just as it does in the case where nominal wage cuts are not resisted. However, these output and employment effects are more intense in the former case, especially at low inflation rates.

6.7 Medium- to Long-Term Macroeconomic Effect of Inflation Reduction, with and without the Downward Nominal Wage Rigidity Assumption

Chapter 5 describes how inflation reduction affects the equilibrium model in the case where workers do not resist nominal wage cuts.[127] The key variable that links the other equilibrium variables to the inflation target is the risk premium in long-term equilibrium interest rates. The equilibrium risk premium depends positively on *excess inflation* defined as the rate of inflation in the consumer price index in excess of 3 percent.[128]

As discussed earlier in this chapter, the downward nominal wage rigidity assumption does not affect the equilibrium relative wage directly. It does, however, affect the

[127] See section 2 of chapter 5.

[128] Chapter 5 notes that although the 3 percent threshold is arbitrary, it is nevertheless justified on the basis

equilibrium risk premium by raising inflationary expectations. Section 6.3 has shown that when workers resist nominal wage cuts, inflationary expectations tend to be higher, in particular when monetary policy targets low inflation rates. The higher inflationary expectations raise the equilibrium risk premium and cause long-term equilibrium interest rates to rise. The higher interest rates raise the equilibrium user cost of capital and reduce the equilibrium rate of capital accumulation.

On the supply side, the lower equilibrium capital stock reduces production capacity. On the demand side, the lower equilibrium investment expenditures reduced aggregate demand. The higher interest rates may also appreciate the equilibrium real exchange rate and thereby reduce equilibrium net exports. However, the higher equilibrium interest rates generate positive wealth effects that tend to raise equilibrium consumption expenditures and aggregate demand. If aggregate demand falls relative to the output level consistent with the equilibrium capital stock and the equilibrium employment rate, equilibrium total factor productivity will fall, causing equilibrium labour income also to fall. Consequently, real output and employment will fall.

6.7.1 Medium to Long-Term Effect of Two Percentage Points Reduction in Inflation Target, with and without the Downward Nominal Wage Rigidity Assumption

When the inflation target is reduced two percentage points from 7 percent to 5 percent, inflation expectations fall by 1.7 percent in the downward nominal wage rigidity model and by 1.8 percent in the baseline model. The lower inflation expectations reduce the equilibrium risk premium by 8 basis points in both models, causing equilibrium real long-term interest rates to fall by 6 basis points in the downward nominal wage rigidity model compared with 8 basis points in the baseline model. The lower inflation causes the equilibrium price of investment goods to be lower by approximately 0.2 percent in both models. The lower price for investment goods combine with the lower equilibrium

of the monetary policy debate in the 1990s. (See footnote 7).

Table 6.3 Medium- to Long-Term Macroeconomic Effects of Inflation Reduction, with and without the Downward Nominal Wage Rigidity Assumption[1]

	Baseline Model			Nominal Wage Rigidity Model		
	7%-5%	5%-3%	3%-1%	7%-5%	5%-3%	3%-1%
C.EQ	-0.63	-0.66	-0.86	-0.65	-0.61	-0.91
CC.EQ	-0.23	-0.21	-0.23	-0.19	-0.20	-0.18
FA.EQ	-0.25	-0.24	-0.30	-0.24	-0.21	-0.27
GB.EQ	0.00	0.00	0.00	0.00	0.00	0.00
INV.EQ	1.16	1.01	1.04	0.95	1.03	0.65
K.EQ	0.99	0.82	0.91	0.88	0.81	0.73
NFA.EQ	2.37	1.80	1.90	2.06	1.98	1.40
NETX.EQ	1.30	1.11	1.09	1.18	0.97	1.10
PK.EQ	-0.15	-0.15	-0.18	-0.14	-0.13	-0.17
R.EQ	0.00	0.00	0.00	0.00	0.00	0.00
RL.EQ	-0.08	-0.08	-0.08	-0.06	-0.06	-0.04
RN.EQ	-2.03	-2.03	-2.03	-2.03	-2.03	-2.03
RNL.EQ	-2.14	-2.13	-2.13	-2.11	-2.10	-2.07
RSL.EQ	0.08	0.07	0.08	0.08	0.07	0.07
RT.EQ	-0.08	-0.08	-0.08	-0.08	-0.05	-0.05
TFP.EQ	-0.58	-0.56	-0.70	-0.58	-0.47	-0.71
TW.EQ	-0.18	-0.20	-0.25	-0.20	-0.14	-0.30
U.EQ	0.01	0.01	0.02	0.01	0.01	0.02
W.EQ	-0.35	-0.38	-0.53	-0.38	-0.28	-0.59
Y.EQ	-0.26	-0.30	-0.41	-0.30	-0.30	-0.44
YLAB.EQ	-0.36	-0.40	-0.55	-0.39	-0.39	-0.56
Z.EQ	-0.09	-0.08	-0.11	-0.07	-0.08	-0.09

1. The figures in this table are based on the Equilibrium model.

interest rates to reduce the equilibrium user cost of capital by 23 basis points in the baseline model, and by 19 basis points in the downward nominal wage rigidity model. Consequently, the equilibrium rate of investment rises by 1.0 percent in the downward nominal wage rigidity model compared with 1.2 percent in the baseline model. The higher rate of capital accumulation raises the equilibrium capital stock by 1.0 percent in the baseline model, which is slightly higher than the 0.9 percent increase in the downward nominal wage rigidity model.

The lower equilibrium interest rates reduce equilibrium financial assets by approximately 0.3 percent in both models, creating wealth effects that contribute to the decline in equilibrium consumption expenditures by 0.6 percent in the baseline model and 0.7 percent in the downward nominal wage rigidity model. Although equilibrium interest rates have fallen, the lower inflation expectations appreciate the equilibrium real exchange rate by approximately 0.1 percent in both models and raise equilibrium net exports by 1.3 percent in the baseline model and by 1.2 percent in the downward nominal wage rigidity model. Equilibrium total factor productivity falls by 0.6 percent in both models, signifying a lower aggregate demand relative to the output level consistent with the equilibrium capital stock and equilibrium employment rate. The equilibrium relative wage falls by approximately 0.4 percent in both models, causing labour income to fall by about the same rate. The lower equilibrium labour income and financial assets reduce equilibrium total wealth by 0.2 percent in the downward nominal wage rigidity model, and by a slightly less amount in the baseline model. The lower equilibrium labour income and total wealth reduce equilibrium consumption expenditures by 0.65 in the downward nominal wage rigidity model and by 0.63 in the baseline model. The lower aggregate demand reduce equilibrium output by 0.3 percent in the downward nominal wage rigidity model compared with 0.26 percent in the baseline model, causing the equilibrium unemployment rate to rise by about a percentage point in both models.

Table 6.3 shows that the equilibrium effect of reducing the inflation target from 5 percent to 3 percent is very similar in both models to the case where the target is reduced from 7 percent to 5 percent. When the inflation target is reduced from 3 percent to one percent, the downward nominal wage rigidity model produces slightly stronger effect for most variables compared to the baseline model. In general, the higher inflationary expectations associated with the downward nominal wage rigidity assumption tend to reduce equilibrium consumption expenditures more and raise equilibrium net exports, equilibrium investment expenditures and the equilibrium capital stock less in the downward nominal wage rigidity model. However, most of these differences are small for practical considerations. For example, the equilibrium real output falls by 0.44 percent in the downward nominal wage rigidity model compared to 0.41 percent in the baseline model, and the equilibrium unemployment rate rises by approximately 0.2 percentage points in both models.

The figures discussed in this section suggest that the downward nominal wage rigidity assumption makes little difference with respect to the medium- to long-term effects of inflation reduction on the levels of key macroeconomic indicators.

6.8 Effect of Inflation Reduction on Macroeconomic Stability, with and without the Downward Nominal Wage Rigidity Assumption

Chapter 5 shows that in the absence of downward nominal wage rigidity, reducing the inflation target within the range of 5 percent to 3 percent improves macroeconomic stability.[129] However, reducing the inflation target below 3 percent seems to make a number of macroeconomic variables more volatile. The results are mixed for the range of inflation targets exceeding 5 percent. These results reflect the literature reviewed in chapter 2, which shows that there is no consensus on the relationship between the level of inflation and the variability of inflation and other key macroeconomic variables. This section compares the effect of inflation reduction on macroeconomic stability in the

Table 6.4 Changes in the Standard Deviation of Selected Model Variables, with and without the Downward Nominal Wage Rigidity Assumption[1]

Table 6.4A THE SHORT-TERM (DISEQUILIBRIUM) MODEL

	Baseline Model			Nominal Wage Rigidity Model		
	5%	3%	1%	5%	3%	1%
C	1.08	1.08	1.12	1.03	1.05	1.18
FA	0.98	1.07	1.16	1.00	1.17	1.49
INV	1.08	1.11	1.24	1.03	1.05	1.29
K	0.94	0.88	0.87	0.92	0.84	0.99
NETX	1.02	1.01	0.99	0.97	0.97	1.05
PCDOT	1.04	1.06	1.14	0.98	0.97	1.21
PDOT	1.05	1.08	1.16	0.99	1.00	1.28
R	1.05	1.06	1.17	0.99	0.98	1.23
RL	1.05	1.06	1.15	0.98	0.97	1.20
RN	1.02	1.01	1.13	0.98	0.95	1.21
RNL	1.02	0.99	1.07	0.97	0.92	1.15
RSL	1.05	1.07	1.18	1.00	0.99	1.25
U	1.08	1.18	1.34	1.03	1.09	1.38
W	1.01	1.03	0.94	0.96	0.94	0.87
Y	1.05	1.10	1.17	1.01	1.02	1.18
Z	1.00	0.93	0.87	0.97	0.91	0.97

Table 6.4B THE MEDIUM- TO LONG-TERM (EQUILIBRIUM) MODEL

	Baseline Model			Nominal Wage Rigidity Model		
	5%	3%	1%	5%	3%	1%
C.EQ	1.03	0.96	1.05	1.04	0.95	1.02
CC.EQ	1.01	0.95	1.03	1.01	0.96	1.01
FA.EQ	0.98	0.96	0.90	0.99	0.97	0.94
INV.EQ	1.04	1.00	1.17	1.03	0.94	1.09
K.EQ	1.00	0.99	0.95	1.01	0.99	1.01
RL.EQ	1.00	0.99	0.95	1.00	0.99	0.99
RN.EQ	0.98	0.96	0.90	0.98	0.96	0.94
RNL.EQ	0.98	0.95	0.89	0.98	0.95	0.94
U.EQ	1.00	0.99	0.96	1.00	0.99	1.00
W.EQ	0.99	0.95	0.95	1.00	0.96	0.98
Y.EQ	0.99	0.92	1.00	1.00	0.91	1.00
Z.EQ	1.00	0.99	0.94	1.00	0.99	0.99

1. The standard deviation for each variable is normalized to be one at the 7 percent inflation target.

[129] See section 3.

baseline model with similar results based on the downward nominal wage rigidity model. Table 6.4 contains the standard deviation associated with values of model variables presented in tables 6.2 and 6.3.[130]

The data in table 6.4 are based on stochastic simulations from versions of the baseline and downward nominal wage rigidity models characterized by one percent, three percent, five percent and seven percent inflation targets. The simulation at each inflation target involves 100 replications of history over the period 1960-95. The models simulate different shocks for each of the 100 replications. They also simulate different shocks for each period within a replication. However, both models share the same set of shocks. Therefore differences between the solution from the two models at each inflation target exclusively reflect the effects of the downward nominal wage rigidity assumption.

Each model further averages the average and standard deviation of each variable for the period 1966-92 over the 100 replications to produce a '*grand average*' and a "*grand standard deviation*".[131] In the rest of this chapter, the standard deviation for each model variable refers to the *grand standard deviations*. The model assumes that each inflation regime is permanent. Therefore table 6.4 estimates the *average* effect of inflation reduction over the period 1966-92. The thesis describes changes in the disequilibrium model as short-term in nature, and changes in the equilibrium model as medium- to long-term in nature. The standard deviation for each variable is normalized to be one when the inflation target is set at 7 percent. The data in Panel A of table 6.4 are based on the disequilibrium versions of the baseline and downward nominal wage rigidity models; the data in panel B are based on the corresponding equilibrium version of the models.

Reducing the inflation target tends to reduce volatility because it reduces inflationary

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[130] The standard deviation for variables in the baseline model is reproduced from table 5.3 in chapter 5.

[131] The model has a maximum lag of 3 years and a maximum lead of two years. It therefore produces solution for the period 1963-1993. The average and standard deviation do not include the first three periods (1963-65) and the last period (1993).

expectations. However, as chapter 5 notes, low inflation targets tend to raise the forecast inflation gap (the difference between expected inflation and the inflation target) because agents do not consider lower inflation to be more credible than higher inflation.[132] In general, these conditions cause inflation forecasts to rise significantly in anticipation of inflationary shocks and fall considerably shortly after those shocks have occurred and the desired monetary policy is in place.

The downward nominal wage rigidity model affects macroeconomic stability in two ways. First, the assumption reduces volatility in the relative wage, especially at low inflation rates, by preventing sharp declines in the event of negative shocks without necessarily raising it (the relative wage) excessively in the event of positive shocks.[133] This way, the downward nominal wage rigidity assumption tends to improve macroeconomic stability by reducing volatility in the relative wage, the unemployment rate, labour income, disposable income, consumption expenditures, real output and commodity prices. Second, earlier discussion in this chapter shows that the downward nominal wage rigidity assumption generally raises inflationary expectations relative to the baseline case. Higher inflationary expectations tend to raise the forecast inflation gap and therefore attract stronger monetary policy responses, which make many macroeconomic variables more volatile.

Table 6.4A reveals some similarities as well as differences between the way inflation reduction affects the standard deviation of key macroeconomic variables in the short run, with and without the downward nominal wage rigidity assumption. Chapter 5 has already discussed the data based on the baseline model.[134] The figures show that inflation reduction improves macroeconomic stability when the inflation target is set within the

[132] See chapter 5, section 3.
[133] According to table 6.2, the disequilibrium relative wage in the baseline model is 3.9 percent below its equilibrium counterpart when the inflation target is set at one percent; in the downward nominal wage rigidity model, the disequilibrium relative wage is less than 0.3 percent below its equilibrium counterpart. On the other hand, while the relative wage in the baseline model coincides with its equilibrium counterpart when the inflation target is set at 7 percent, the relative wage in the downward nominal wage rigidity model is only 1.2 percent above its equilibrium counterpart.

range of 5 percent to 3 percent. However, moving the target lower to the neighbourhood of 1 percent makes many macroeconomic indicators more volatile in the short run because monetary policy becomes more aggressive. Volatility of real consumption expenditures, financial assets, real investment spending and interest rates rise the most. Most of the other variables become only slightly volatile. A number of variables, including the capital stock, the real exchange rate and net exports become increasingly stable at lower inflation rates.

Under the downward nominal wage rigidity assumption, reducing the inflation target from 3 percent to 1 percent makes most variables even more volatile than in the baseline case. Unlike the baseline scenario, however, reducing the inflation target either from 7 percent to 5 percent or from 5 percent to 3 percent reduces volatility slightly for most variables. Thus, at moderate to high inflation targets, the downward nominal wage rigidity assumption producing a stabilizing effect through the relative wage that more than offsets the destabilizing effect it creates through higher inflation expectations. However, at low inflation targets, inflationary expectations become more volatile and reduce stability in most variables. The exceptions are real consumption expenditures, financial assets, net investment expenditures, the unemployment rate and real output, which become increasingly volatile at low inflation targets, just as in the case of the baseline model.

Table 6.4B compares the stability in the equilibrium versions of the baseline and downward nominal wage rigidity models. Again, the data on the baseline model is reproduced from table 5.3B to facilitate comparison of the two models. The table shows that unlike the case of the disequilibrium models, inflation reduction affects the stability of equilibrium variables in the baseline and downward nominal wage rigidity models in very similar ways. In both cases, reducing the inflation target from 7 percent to 5 percent has very little effect on the volatility of key macroeconomic variables. However, virtually all the variables become less volatile when the inflation target is reduced from 5 percent

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[134] The first block of table 6.4A reproduces table 5.3A to facilitate comparison between the two models.

to 3 percent. The equilibrium values of real consumption expenditures, the user cost of capital, net investment expenditures, the capital stock, the unemployment rate and real output are just about as volatile at the one percent inflation target as they are at the 7 percent inflation target. Besides these, all the equilibrium variables become consistently and increasingly stable at lower inflation targets.

In general, reducing the inflation target from originally high levels increases short-term volatility in the baseline model but improves stability in the downward nominal wage rigidity model because of the stabilizing effect of the downward nominal wage rigidity assumption. However, reducing the inflation target in the neighbourhood of one percent increases volatility in both models, particularly the downward nominal wage rigidity model because it generates higher inflationary expectations. This observation suggests that improving policy credibility in the model by making agents take the inflation target more seriously in their expectations formation will most likely improve stability in the downward nominal wage rigidity model more than in the baseline model at all inflation targets.

Inflation reduction seems to generally improve long-term macroeconomic stability in both models for the range of inflation targets analyzed in this thesis. However, the best performance occurs at moderate inflation rates.

CHAPTER 7:SUMMARY, CONCLUSIONS AND EXTENSION

Some analysts have attributed the increasing popularity of direct inflation targeting among central banks over the last two decades to the emerging consensus within the economics profession that activist monetary policy leads to higher inflation in the long run without real output and employment gains. At least four intellectual developments, along with actual events, have contributed to this view. First, Monetary policy is deemed to have long and variable lags; therefore activist monetary policy can potentially exacerbate fluctuations in real output. Second, it is generally accepted that there is no long-run trade-off between inflation and unemployment. Third, agents' expectations about future monetary policy tend to influence the wage- and price-setting behaviour in the economy - the so-called time-inconsistency problem. Fourth, price stability or low inflation is generally perceived to promote economic efficiency.

Low inflation is perceived to be efficient because it reduces the cost of economizing on non-interest bearing money (the so-called shoe-leather cost of inflation); because it promotes more productive investment by preventing excessive investment in the financial sector; and because it reduces market uncertainties and thereby reduces investment costs and promotes efficient long-term contracts. Moreover, it reduces the misallocation of capital that arises from the interaction of higher inflation and a tax system that is not fully indexed. Some researchers have also produced evidence that lower inflation reduces inflation volatility and increases economic growth.

Beginning with the then Governor John Crow's Hanson Lecture at the University of Alberta in January 1988, the Bank of Canada actively promoted price stability as the long-term objective of monetary policy before formally adopting inflation targets on February 26, 1991. In general, an inflation target serves as a nominal anchor that reduces the inflationary bias produced by the time-inconsistency problem. The Bank of Canada has tried other forms of nominal anchors in the past, including a target growth path for monetary aggregates, mainly M1 and M2; a target band for the dollar relative to the U.S dollar; and a target growth path for nominal income. Monetary aggregates have become increasingly difficult to target because recent financial innovations have made the velocity of money very unstable; a fixed exchange rate erodes Canada's control over its own monetary policy; and targeting nominal income requires the monetary authority to announce the potential GDP and its growth rate. (Estimating the potential GDP has typically been problematic. Moreover the public is less familiar with the concept of nominal GDP).

Inflation targets also have their limitations. For example, it is difficult to achieve the inflation target with precision because monetary policy has long and variable lags. Moreover, inflation targeting may lead to greater output variability if the targets are rigidly interpreted. However, the Bank of Canada's approach to inflation targeting has been cautious, taking contemporary views about transparency, accountability and credibility of monetary policy seriously. As in the case of New Zealand which adopted formal inflation targets one year ahead of Canada, the prolonged campaign to promote price stability prior to the adoption of formal inflation targets is believed to have substantially reduced inflationary pressures, and thereby reduced the potential recessionary effect of the policy. Second, the inflation targets were jointly announced by the then Minister of Finance, Michael Wilson, and the then governor of the Bank of Canada, John Crow. This cooperation between the two entities that can influence monetary policy increased the perceived credibility of the policy. Third, the Bank chose the consumer price index, which most agents understand, use and forecast frequently, as the target variable. This choice improved transparency and accountability on the part of the Bank of Canada. Fourth, the entity that measures the consumer price index (Statistics Canada) is independent of the Bank of Canada who implements the targets and assesses past performance. Fifth, the Bank of Canada constructed the monetary conditions index (MCI) as a short-term operating target. The method for calculating the index is simple enough for the public to understand, and the Bank publishes the index on a regular basis.[135][136] Moreover, the Bank redesigned its *Annual Report* to provide more non-technical information to the public including reviews of monetary policy and the success of inflation targeting.

The Bank of Canada's inflation targeting is also flexible in practice. Unlike the Bank of England and the Bundesbank, the Bank of Canada states its inflation target as a range rather than a point target, often with greater emphasis placed on the bands than on the midpoint. Moreover, like the Bank of England and the Bundesbank, and unlike the Reserve Bank of New Zealand, the Bank of Canada pays attention to real output growth. Focusing on the bands for the inflation target allows considerable flexibility to accommodate short-term aggregate supply shocks without causing unnecessary disturbance to real output growth. This leads some analysts to view Canada's inflation targeting as "a way to help dampen cyclical fluctuations in economic activity"[137].

Notwithstanding the operational ingenuity, Canada's adoption of inflation targets at the beginning of the 1990s coincided with an economic recession followed by a sluggish recovery that lasted over half of a decade. Some analysts have linked Canada's poor economic performance in the first half of the decade relative to the United States to the monetary policy pursued over this period. Critics argue that when monetary policy focuses on keeping inflation low, the effort to manage inflationary pressures to that end results in relatively tight monetary policy that tends to reduce aggregate demand, the capital stock, real output and employment. For example, Fortin(1996) argues that the increase in the average Canada-U.S real short-term interest rate differential from 0.9 percent between 1980 and 1988 to 3.6 percent between 1989 and 1996 reflect excessive tightening of monetary policy associated with the low inflation targets.

[135] The monetary conditions index is a weighted sum of changes in the ninety-day commercial paper interest rate and in the Group of Ten trade-weighted Canadian dollar exchange rate; the weights are three to one.
[136] Canada's inflation targeting involves constrained discretion. As a result, the Monetary Conditions Index does not correctly predict monetary policy. Some analysts have criticized the MCI on that basis. See Mishkin (2000).
[137] Mishkin and Posen (1999)

Although the empirical literature shows evidence of these policy-induced *recessions*; there is no consensus on their magnitude and degree of persistence. Researchers have produced sacrifice ratios raging from less than 2.0 to about 4.7.[138] The conventional view is that these costs are relatively short lived; they are more important during the transitional period when credibility of the policy is not well established and when agents expectations are not fully adjusted to the low inflation environment. Perhaps the most important and direct source of differences in the estimates of the welfare effect of inflation reduction is the assumptions about the aggregate relationship between price inflation and the unemployment rate (i.e. the properties of the Phillips curve). Researchers have suggested at least five major conjectures for the Canadian Phillips curve Fortin (1997). First, the possibility that a structural change increased the non-accelerating inflation rate of unemployment (NAIRU) from 7.5% in the 1980s to over 9% in the 1990s; second, the possibility that there is unemployment hysteresis; third, the possibility that the short-run Phillips curve is non-linear; fourth, the possibility that the process by which agents form expectations changes when monetary policy regime changes; and finally, the possibility that workers resist nominal wage cuts.

Fortin(1997) finds support for only two of these conjectures: a structural break around 1991 and downward nominal wage and price rigidities. He corroborates these results with Fortin(1996) and a similar study by Akerlof, Dickens and Perry(1996, based on U.S data) and concludes that downward nominal wage rigidity has played an important role in Canada's experience with persistent high unemployment throughout the first half of the 1990s. Subsequently, researchers working with the Canadian wage settlements data have confirmed that the percentage change in base-rate settlements is approximately normally distributed in periods with moderate to high inflation rates. When inflation rates are low, however, the distribution becomes positively skewed with a prominent spike at zero

[138] The sacrifice ratio is the percentage fall in the GDP required to reduce the rate of inflation by a percentage point. The literature review in chapter 2 discusses these estimates in detail.

percent.[139] That is, base wage freezes are more frequent in periods of low inflation. These observations have been generally interpreted as evidence of downward nominal wage rigidity in the Canadian labour market.

Hogan(1998) argues that the current monetary policy debate in Canada must address a number of key issues; in particular, whether nominal wages are downwardly rigid in Canada so that low inflation produces higher real wages than would otherwise be the case; whether higher real wages lead to higher unemployment in Canada; and whether the welfare cost of higher unemployment outweighs the benefits of low inflation.

No consensus has been reached as yet on any of these major issues. This thesis constructs a model based on the Bank of Canada's Canadian Policy Analysis Model (CPAM). In the context of this model, the thesis studies the short-term and medium- to long-term macroeconomic effects of reducing the inflation target two basis points from different initial inflation levels in the absence of downward nominal wage rigidity. The results show that within the range of 1 percent to 7 percent, reducing the inflation target reduces real output and raises the unemployment rate because a percentage-point of inflation reduction requires progressively tighter monetary policy when the inflation target is already low. These policy-induced macroeconomic effects are strong in the short run but become very weak in the medium to long run. On the other hand, the policy appears to improve macroeconomic stability when the inflation targets are set within the range of 5 percent to 3 percent. However, moving the target lower to the neighbourhood of 1 percent makes many macroeconomic variables more volatile in the short run because monetary policy becomes more aggressive.

Based on earlier research on the significance of downward nominal wage rigidity in the

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[139] See Simpson, Cameron and Hum(1998) and Crawford and Harrison(1997). The base wage is defined as the wage rate for the lowest-paid job category containing a significant number of employees. Crawford and Harrison(1997) note that the data coverage in recent years is approximately 55 percent of unionized employees and 20 percent of all paid non-agricultural employment in Canada; but only about 10 percent of paid employees in the private, non-agricultural sector.

Canadian labour market, this thesis further introduces the downward nominal wage rigidity assumption into the original model, and then repeats the analysis of short-term and medium- to long-term macroeconomic effects of reducing the inflation target two basis points from different initial inflation levels. It then compares these results with those generated from the model that does not include the downward nominal wage rigidity assumption. The results suggest that when workers resist nominal wage cuts, inflation reduction reduces real output and employment on short-term basis just as it does in the case where nominal wage cuts are not resisted. However, these output and employment effects are more intense in the former case, especially at low inflation rates.

The downward nominal wage rigidity assumption seems to make little difference with respect to the medium- to long-term effects of inflation reduction. The long-term effect of reducing the inflation target from 5 percent to 3 percent is very similar in both models to the case where the target is reduced from 7 percent to 5 percent. However, when the inflation target is reduced from 3 percent to one percent, the downward nominal wage rigidity model produces slightly stronger effect on most variables than the baseline model because the former produces higher inflationary expectation at all the inflation targets included in this study.

In general, reducing the inflation target from originally high levels increases short-term volatility in the baseline model but improves stability in the downward nominal wage rigidity model because of the stabilizing effect of the downward nominal wage rigidity assumption. However, reducing the inflation target in the neighbourhood of one percent increases volatility in both models, particularly the downward nominal wage rigidity model because it generates higher inflationary expectations relative to the inflation target. Inflation reduction seems to improve long-term macroeconomic stability in both models for the range of inflation targets analyzed in this thesis. However, the best performance occurs at moderate inflation rates.

The analysis undertaken in this thesis can be extended in several ways. First, it is possible to experiment with varying degrees of policy credibility. The more agents perceive the monetary authority's inflation targets to be credible, the more will those targets influence their inflation expectations. Credible inflation targets will reduce inflationary expectations, and thereby cause monetary policy to be less restrictive than would otherwise be the case. Consequently, the output and employment costs of inflation reduction will be lower than would otherwise be the case.

Second, the stochastic shocks used in the simulation exercises are essentially aggregate demand shocks emanating from business investment expenditures, households consumption expenditures, the real exchange rate and the yield curve. It is possible to extend this list to include supply-side disturbances such as productivity shocks that affect either factor productivity or the price level. These shocks are likely to make the output and employment effects of inflation reduction more persistent. Thirdly, it is possible to divide the simulation period (1963-1993) into shorter sub-periods, and study the macroeconomic effects of inflation reduction over shorter periods than this thesis has done.

Fourth, the dynamic interaction between the equilibrium and the disequilibrium sub-models can be improved. As chapter 3 explains, the disequilibrium model includes all dynamics arising from the equilibrium model in addition to its own unique short-term dynamics. However, dynamics originating from the disequilibrium model, including those associated with monetary policy, have limited influence on the equilibrium model. This feature is probably not problematic since the literature does not show strong evidence of hysteresis. However, modifying the overall model structure to allow greater dynamic feedback from the disequilibrium model to the equilibrium model will produce useful insight about the qualities of the model.

Finally, Hogan(1998) argues that the output and employment effects of inflation reduction under downward nominal wage rigidity may be different if employers anticipate wage resistance and therefore incorporate that expectation into wage contracts.

In that situation, the equilibrium relative wage may follow an entirely different path, and thereby condition the short-term (disequilibrium) relative wage to be lower than would otherwise be the case.

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APPENDIX 1: GRAPHS FOR SELECTED VARIABLES FROM A DETERMINISTIC SIMULATION.

Figure 4.2 **Graphs of selected variables from a deterministic simulation**

(The index "HS" denotes historical data series and "EQ" denotes simulated equilibrium values. The simulated short-run disequilibrium values have no index attached)

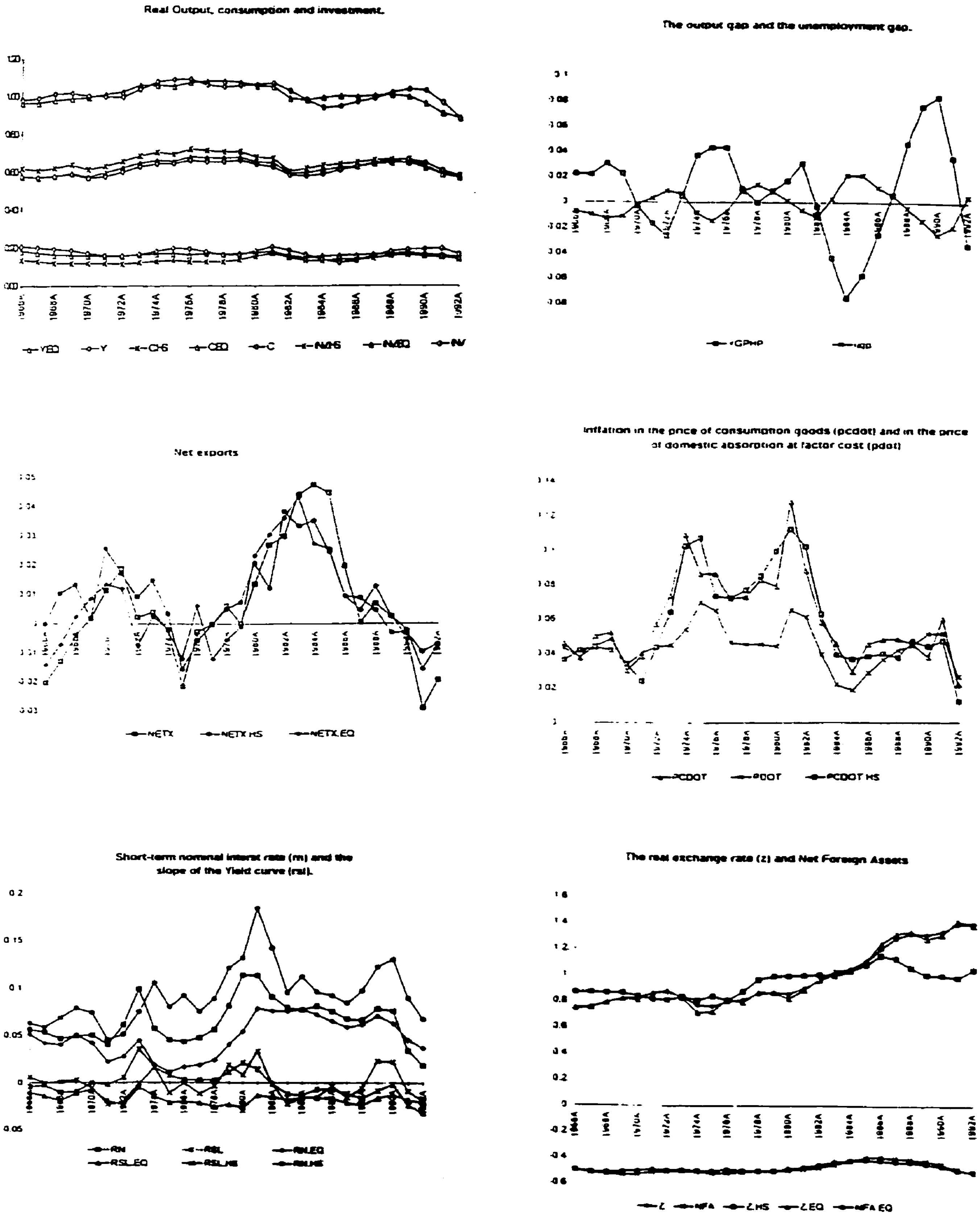
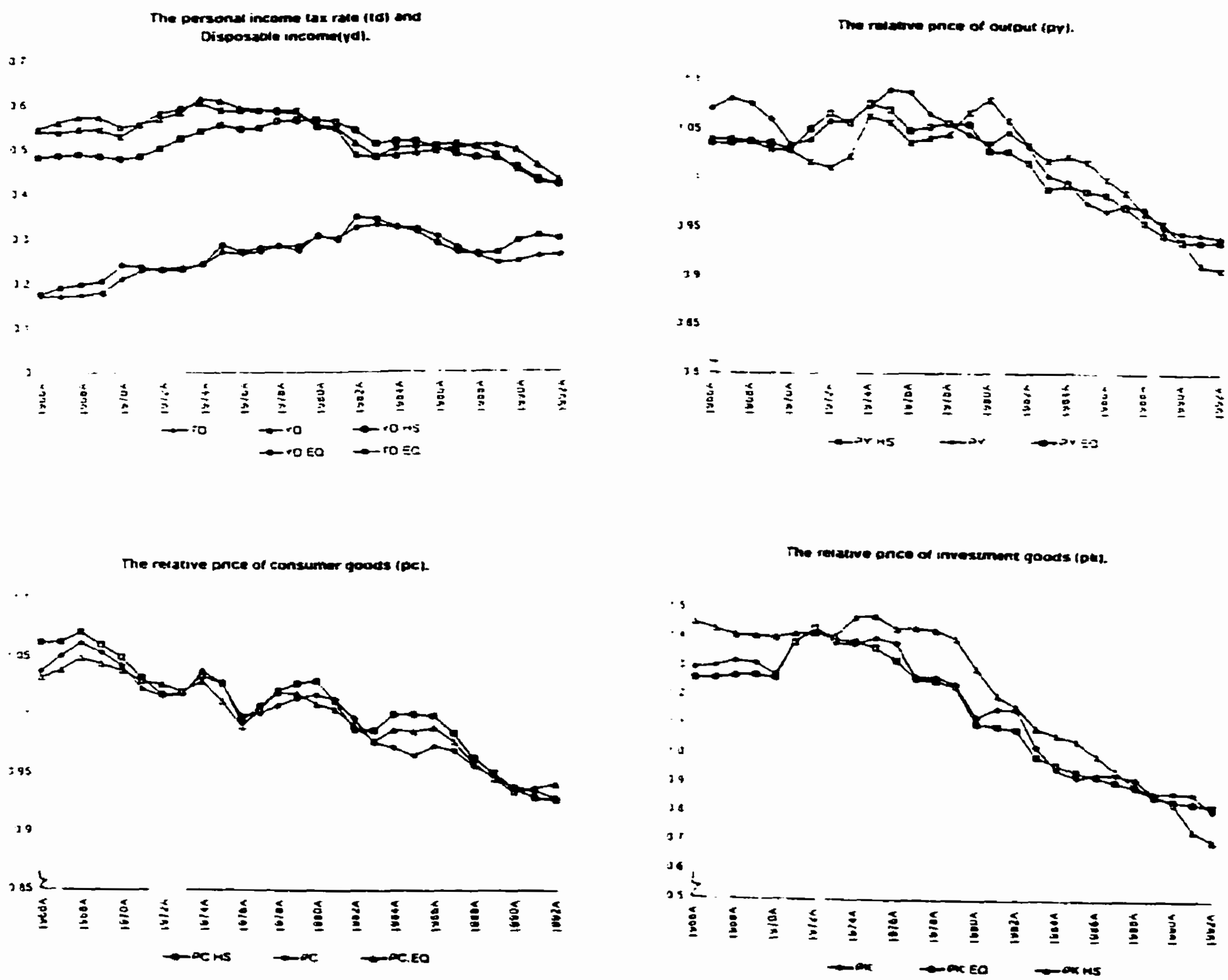


Figure 4.3 **Graphs of selected variables from a deterministic simulation**

(The index "HS" denotes historical data series and "EQ" denotes simulated equilibrium values. The simulated short-run disequilibrium values have no index attached)



APPENDIX 2: DYNAMIC RESPONSES OF SELECTED VARIABLES TO TEMPORARY DETERMINISTIC SHOCKS

(Extension from figures 4.4 & 4.5 in chapter 4)

Figure 4.6 Responses of selected variables to a temporary increase in total factor productivity
(% is percent shock minus control; %p is percentage points shock minus control)

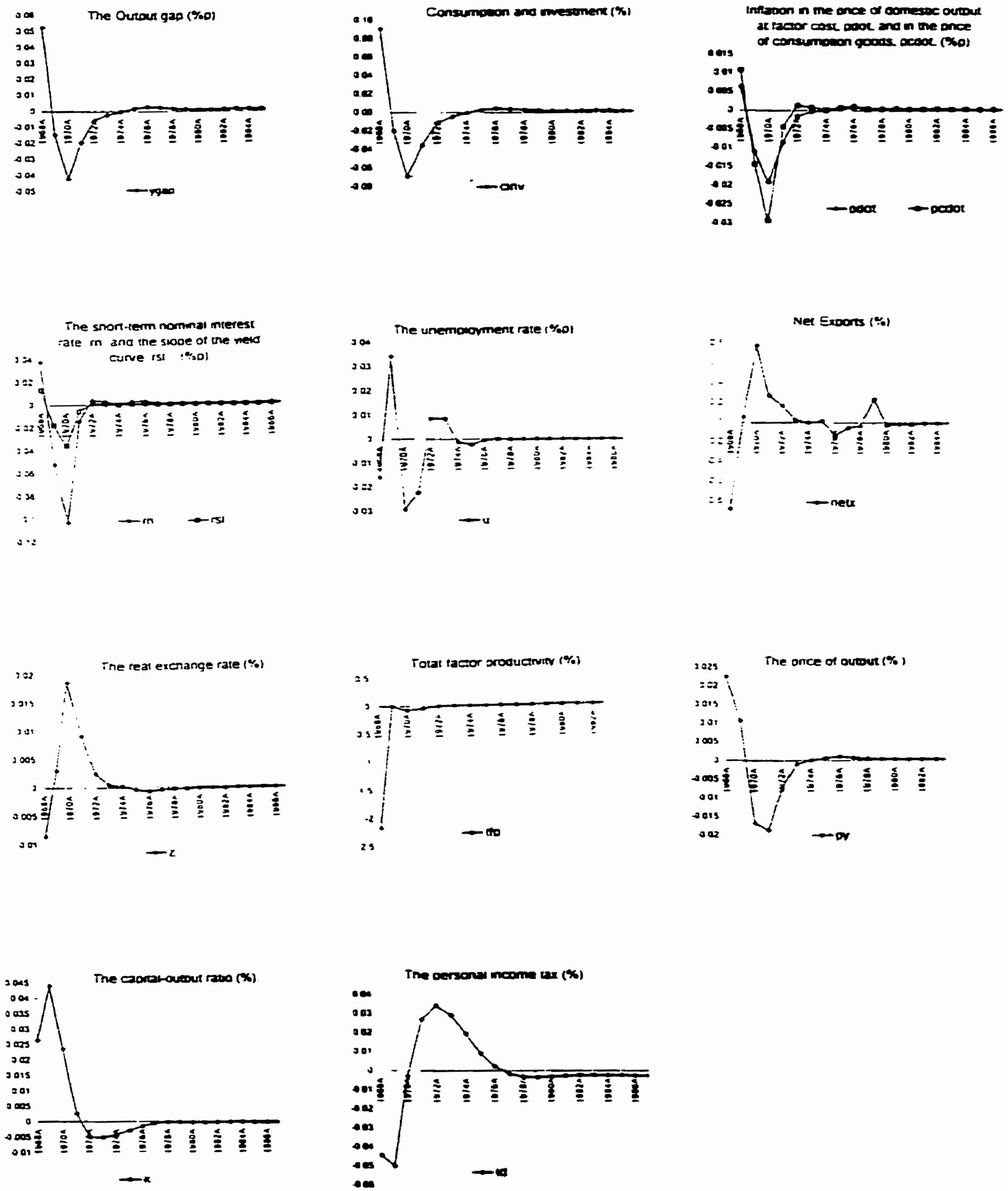


Figure 4.7 Responses of selected variables to a temporary increase in the real exchange rate.
(% is percent shock minus control; %p is percentage points shock minus control)

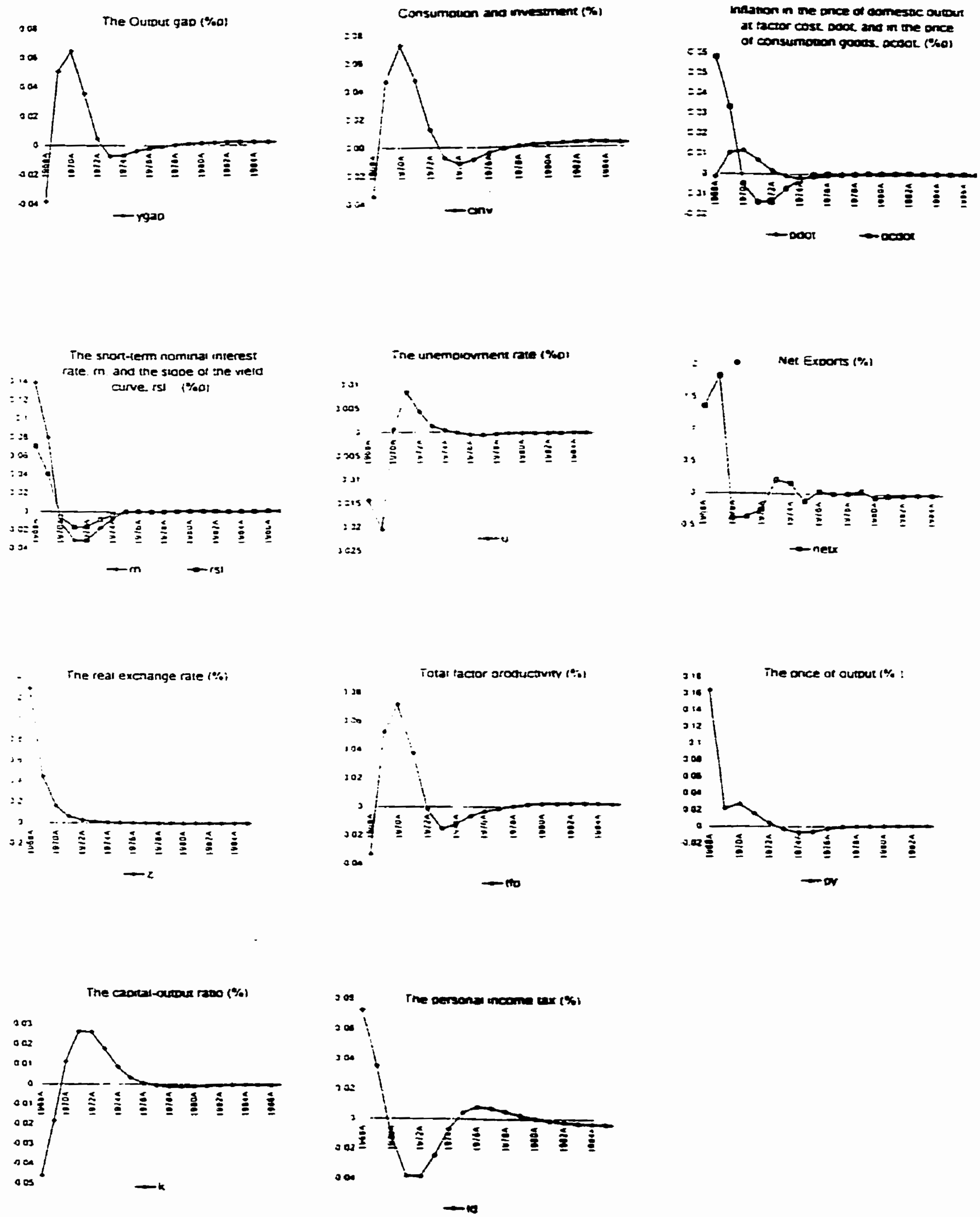


Figure 4.8 Responses of selected variables to a temporary increase in the relative price of output.

(% is percent shock minus control; %p is percentage points shock minus control)

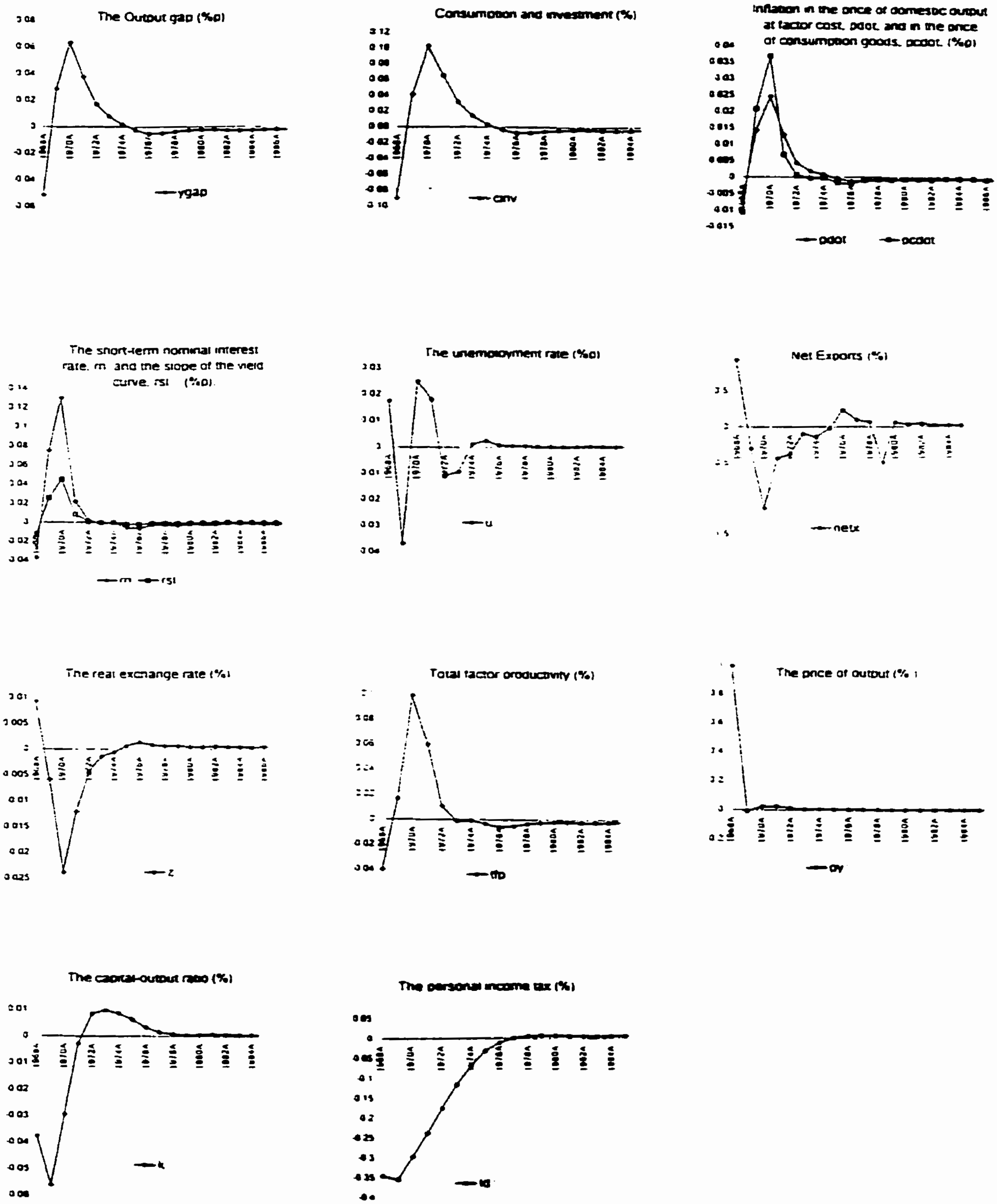
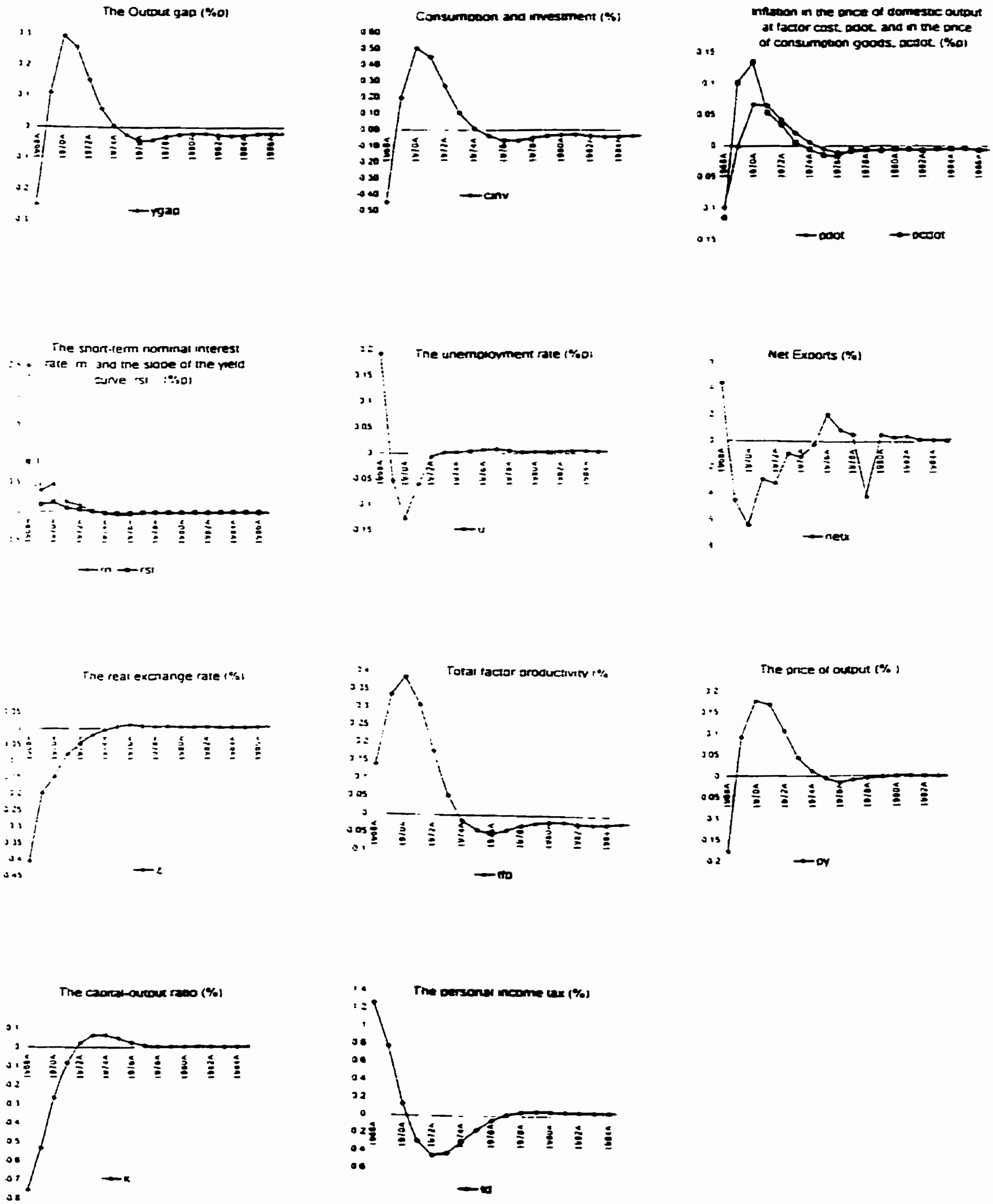


Figure 4.9 Responses of selected variables to a temporary increase in the price of the slope of the yield curve.

(% is percent shock minus control; %p is percentage points shock minus control)



APPENDIX 3:

Calculating Impulse Responses From The Linear VAR Model

The matrix COEFF contains the coefficients estimated from the VAR and summarized in table 4.2. The matrix CORR contains the estimated residual correlation matrix.[140] The restrictions implicit in the causal ordering (4.8) make CORR a lower triangular matrix,

$$\mathrm{COEFF} = \begin{bmatrix} 0.971 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.368 & 0 & 0 & 0 & 0 \\ 0.326 & 0.098 & 0.895 & 0.044 & 0.073 & -1.302 \\ 0.067 & 0.176 & 0.082 & 0.636 & 0.07 & -9.19\cdot 10^{-3} \\ 0.092 & -7.07\cdot 10^{-3} & -0.166 & 0.083 & 0.752 & -0.604 \\ -0.11 & 0.054 & 0.167 & 2.38\cdot 10^{-3} & 0.065 & 0.239 \end{bmatrix}.$$

$$\mathrm{CORR} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0.239 & -0.113 & 1 & 0 & 0 & 0 \\ 0.208 & -0.04 & 0.262 & 1 & 0 & 0 \\ -0.068 & -0.019 & -0.452 & -0.368 & 1 & 0 \\ 0.315 & -0.039 & 0.428 & 0.505 & -0.191 & 1 \end{bmatrix}.$$

The standard deviation extracted from the estimated variance-covariance matrix combine with these matrices to produce impulse responses to one-standard deviation innovation in each of the six variables. The rows and columns of all the matrices presented in this section are arranged according to the Wold causal ordering specified in chapter 4 (i.e. yp, pxrow, c+i, py, z and rsl from left to right for rows, and from top to bottom for columns). The first variable on each row is the dependent variable. For example, the first row expresses potential output (*yp*) as a function of its own one-period lagged value, and one-

[140] Since yp and pxrow are exogenous in the VAR, their correlation coefficients with the rest of the

period lagged values of the domestic price of exports (*pxrow*), consumption and investment (*c+i*), the relative price of output (*py*), the real exchange rate (*z*), and the slope of the yield curve (*rsl*) respectively.

Sd is the vector of standard deviation calculated from the variance-covariance matrix and augmented by the historical standard deviation of *yp* and *pxrow*. When *sd* is multiplied by an identity matrix, it produces the diagonal matrix *Isd*. Multiplying *Isd* by the correlation coefficient matrix *CORR* produces *SDCORR*, a diagonal matrix with the standard deviation of the VAR variables on the main diagonal. By definition, the entries in SDCORR represent contemporaneous impulse responses to a one-standard deviation innovation in each of the variables.

$$sd = \begin{bmatrix} 8.27\cdot 10^{-3} \\ 0.067 \\ 0.02 \\ 0.011 \\ 0.045 \\ 0.011 \end{bmatrix}, \qquad Isd = \begin{bmatrix} 8.27\cdot 10^{-3} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.067 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.02 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.011 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.045 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.011 \end{bmatrix},$$

$$SDCORR = \begin{bmatrix} 8.27\cdot 10^{-3} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.067 & 0 & 0 & 0 & 0 \\ 1.978\cdot 10^{-3} & -7.573\cdot 10^{-3} & 0.02 & 0 & 0 & 0 \\ 1.723\cdot 10^{-3} & -2.707\cdot 10^{-3} & 5.303\cdot 10^{-3} & 0.011 & 0 & 0 \\ -5.595\cdot 10^{-4} & -1.26\cdot 10^{-3} & -9.159\cdot 10^{-3} & -4.1\cdot 10^{-3} & 0.045 & 0 \\ 2.606\cdot 10^{-3} & -2.633\cdot 10^{-3} & 8.661\cdot 10^{-3} & 5.623\cdot 10^{-3} & -8.511\cdot 10^{-3} & 0.011 \end{bmatrix},$$

---

variables are taken from the actual (historical) data.

To derive impulse responses to lagged innovations in the variables, a subsidiary coefficient matrix (Q) is defined as $Q_r = M^{r-1}$, where r = 1, 2, ... is the number of periods for which impulse responses are calculated.[141] Multiplying Q_r by SDCORR produces the impulse response matrices IRM_r, r = 1,2, ... According to the definition of Q_r, Q_1 is an identity matrix, and therefore IRM_1 coincides with the matrix SDCORR which represents contemporaneous responses to innovations in the variables. Similarly, IMR_2 produces impulse responses one period after the shock.[142] The contemporaneous impulse responses (IRM_1) and impulse responses 5 periods after the shock (IRM_6) are illustrated below. As in COEFF, rows and columns of IMR_r are arranged according to the Wold causal ordering (i.e. yp, pxrow, c+i, py, z and rsl from left to right for rows, and from top to bottom for columns). The columns represent the variables being shocked; the first variable on each row is the one responding to the shocks. For example, the first row represents responses of potential output (yp) to its own innovations and to innovations in the domestic price of exports (pxrow), consumption and investment (c+i), the relative price of output (py), the real exchange rate (z), and the slope of the yield curve (rsl).

$$IRM_1 = \begin{pmatrix} 8.27\cdot10^{-3} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.067 & 0 & 0 & 0 & 0 \\ 1.978\cdot10^{3} & 7.573\cdot10^{-3} & 0.02 & 0 & 0 & 0 \\ 1.723\cdot10^{-3} & -2.707\cdot10^{3} & 5.303\cdot10^{-3} & 0.011 & 0 & 0 \\ 5.595\cdot10^{4} & -1.26\cdot10^{3} & -9.159\cdot10^{-3} & -4.1\cdot10^{-3} & 0.045 & 0 \\ 2.606\cdot10^{-3} & -2.633\cdot10^{-3} & 8.661\cdot10^{-3} & 5.623\cdot10^{-3} & -8.511\cdot10^{-3} & 0.011 \end{pmatrix}$$

[141] r=1 represents the impact period; r=2 represents one period after the shock is imposed; etc.
[142] Q_2 coincides with the coefficient matrix COEFF.

$$IRM_6 = \begin{pmatrix} 7.123\cdot 10^{-3} & 0 & 0 & 0 & 0 & 0 \\ 0 & 4.534\cdot 10^{-4} & 0 & 0 & 0 & 0 \\ 0.011 & -8.697\cdot 10^{-4} & -1.353\cdot 10^{-3} & -3.262\cdot 10^{-4} & -2.127\cdot 10^{-3} & -1.941\cdot 10^{-3} \\ 2.71\cdot 10^{-3} & 3.98\cdot 10^{-3} & -1.414\cdot 10^{-3} & 1.849\cdot 10^{-4} & 4.446\cdot 10^{-3} & -1.923\cdot 10^{-3} \\ -5.504\cdot 10^{-4} & -1.021\cdot 10^{-3} & -4.19\cdot 10^{-3} & 2.861\cdot 10^{-3} & 3.184\cdot 10^{-3} & 6.198\cdot 10^{-3} \\ 8.201\cdot 10^{-4} & 1.464\cdot 10^{-4} & -1.412\cdot 10^{-3} & -6.037\cdot 10^{-4} & 1.713\cdot 10^{-3} & -1.528\cdot 10^{-3} \end{pmatrix}$$

APPENDIX 4: Calculating Structural Shocks Based on Impulse Responses from the Linear VAR

Equation (4.9) specifies, in vector notation, the VAR estimated in chapter 4. The column vector x_t contains the VAR variables, yp, pxrow, c+i, py, z and rsl. The data generating process for each variable consists of a deterministic process, $b(L)X_t$, and a stochastic process ($\omega\varepsilon_t$) that arises from shocks to all six variables. In vector notation,

$$\mathbf{x}_t = \mathrm{B(L)}\mathbf{x}_{t-1} + \Omega\varepsilon_t, \qquad \varepsilon\sim\mathrm{N}(0,\mathrm{I}) \qquad (4.9)$$

where **x** is the 6X1 column vector of VAR variables, **B** is a 6X6 matrix of coefficients, $\Omega^T\Omega$ is the 6X6 variance-covariance matrix of the VAR, ε is the 6X1 column vector of iid shocks, and I denotes a 6X6 identity matrix.

Since the VAR is linear in the shock terms, the stochastic term may be viewed as originating from the six impulse response functions rather than a single multivariate shock term, ε. Multiplying the iid shock term in equation (4.9) by ι^j where ι^j is a row vector with one on the *jth* column and zero elsewhere, produces the *jth* impulse response function.[143] That is,

$$\mathbf{x}_t = \mathrm{B(L)}x_{t-1} + \Omega\iota^1\varepsilon_{1t} + \ldots + \Omega\iota^6\varepsilon_{6t} \quad , \qquad \varepsilon\sim\mathrm{N}(0,\mathrm{I}) \qquad (4.9)$$

A deterministic simulation of the model produces an estimate $b(L)X_{t-1,}$ of $B(L)x_{t-1}$ for each of the six VAR variables and for all other endogenous variables in the structural model. Let $f_i(.)$ be the function that produces $b_i(L)X_{t-1}$ for each variable i in the VAR, and let $IRV_i^j(t)$ denote the impulse responses derived from the linear VAR. That is, $IRV_i^j(t)$ is the

[143] j = 1,2, .., 6 refers to the position of the variable being shocked in the World ordering specified in section 3.4.2; i = 1,2, .., 6 refers to the position of the variable responding to the shock.

impulse response by VAR variable i to innovations in VAR variable j. It is possible to obtain the series of shocks $\varepsilon_i^j(t)$ necessary for $f_i(.)$ to produce $IRV_i^j(t)$ relative to the control $b(L)X_{t-1}$. These shock series are obtained ("*backed out*" of the model) by performing a deterministic simulation in which the structural equation in the short-term (disequilibrium) model for each of the six VAR variables is replaced by its counterpart equation,

$$b_i(L)X_{t-1} = f_i(.) + IRV_i^j(t) + \varepsilon_i^j(t) \qquad (4.10)^{144}$$

The shock series $\varepsilon_i^j(t)$ derived endogenously from equation (4.10) possess the characteristics that will enable the non-linear structural model to produce impulse responses that have similar correlation patterns as $IRV_i^j(t)$ from the linear VAR.

These shock series are truncated after two periods (two years), and treated as *shock coefficients* for random shocks drawn from a standard normal distribution.[145] Each random shock drawn from the standard normal distribution is subsequently modeled as a serially correlated shock based on the *truncated shock coefficients*. Since the shock series are truncated after two periods, the resulting shock terms will follow a first-order Autoregressive (AR(1)) process. These serially correlated shock terms are aggregated across impulses and across the two periods to produce unique final shock term (*ishk*) for each variable in the VAR. These shock terms are included in the equations that determine the six VAR variables in the short-term (disequilibrium) structural model. For example, the final shock term (*invshk*) that enters the structural equation for investment is,

$$invshk_t = c1invt1 * uyp_t + c2invt1 * uyp_{t-1} + c1invt2 * upxrow_t + c2invt2 * upxrow_{t-1}$$
$$+ c1invt3 * ucinv_t + c2invt3 * ucinv_{t-1} + c1invt4 * upy_t + c2invt4 * upy_{t-1}$$

[144] The impact of the single-period shocks implied in $IRV_i^j(t)$ coincide with 1965, and impulse responses are calculated from 1965 to 1995.
[145] It would be ideal to truncate the shock for a period shorter than two years if the shock series are to reflect purely exogenous shocks and non of the feedback effects induced by countercyclical policies. Two years is considered to be the shortest period suitable for this exercise in an annual model.

$$+c1invt5*uz_t+c2invt5*uz_{t-1}+c1invt6*ursl_t+c2invt6*ursl_{t-1}$$

where *Cijk* for $i, k = 1, 2, \ldots, 6$, $j = inv$ are the coefficients calculated as described above; and *ui* (i = *yp, pxrow, py, cinv, z, rsl*) are the random shocks drawn from the normal distribution. The numbers *1, ..., 6* in the coefficients denote the positions of the pair of variables *i* and *j* according to the World ordering used to estimate the VAR chapter 4.

APPENDIX 5: STEADY-STATE SOLUTION OF THE MODEL

	STEADY-STATE VALUES OF ENDOGENOUS VARIABLES	
C	Consumption	0.6521
C.EQ	Equilibrium consumption	0.6521
CC.EQ	Equilibrium user cost of capital	0.1857
FA	Financial assets	1.9077
FA.EQ	Equilibrium financial assets	1.9077
GB	Real government assets	0.5400
GB.EQ	Equilibrium real government assets	0.5400
HW.EQ	Equilibrium human wealth	4.7589
INV	Investment spending	0.1748
INV.EQ	Equilibrium investment spending	0.1748
K	Production capital	1.8402
K.EQ	Equilibrium Production capital	1.8402
M	Imports	0.5087
M.EQ	Equilibrium imports	0.5087
MPCW.EQ	Marginal propensity to consume out of total wealth	0.0782
MPR	Import-penetration ratio	0.2962
MPR.EQ	Equilibrium import-penetration ration	0.2962
NETX	Nex exports	0.0195
NETX.EQ	Equilibrium net exports	0.0195
NFA	Nef foreign assets	-0.4521
NFA.EQ	Equilibrium net foreign assets	-0.4521
PC	Relative price of consumption goods	1.1791
PC.EQ	Equilibrium relative price of consumption goods	1.1791
PFC	Relative price of output at factor cost	0.9854
PFC.EQ	Equilibrium relative price of output at factor cost	0.9854
PG	Relative price of government goods	1.0238
PG.EQ	Equilibrium relative price of government goods	1.0238
PI	Relative price of capital	0.9890
PI.EQ	Equlibrium relative price of capital	0.9890
PK	Relative price of investment goods	0.8898
PK.EQ	Equilibrium relative price of investment goods	0.8898
PM	Relative price of imports	0.9377
PM.EQ	Equilibrium relative price of imports	0.9377
PX	Relative price of exports	0.9890
PX.EQ	Equilibrium relative price of exports	0.9890
PY	Relative price of output	1.1274

PY.EQ	Equilibrium relative price of output	1.1274
R	Short-term real interest rate	0.0280
R.EQ	Equilibrium short-term real interest rate	0.0280
RGB.EQ	Equilibrium real interest on government bonds	0.0439
RK.EQ	Equilibrium real return on capital	0.1051
RL.EQ	Equilibrium long-term interest rate	0.0331
RN	Short-term nominal interest rate	0.0383
RN.EQ	Equilibrium short-term nominal interest rate	0.0383
RNFA	Real interest rate on foreign assest	0.0431
RNFA.EQ	Equilibrium real interest rate on foreign assets	0.0431
RNL	Long-term nominal interest rate	0.0435
RNL.EQ	Equilibrium lon-term nominal interest rate	0.0435
RSL	Slope of the yield curve	-0.0050
RSL.EQ	Equilibrium slope of the yield curve	-0.0050
RT.EQ	Equilibrium term premium on long-term interest rates	0.0000
TD	Personal income tax rate	0.2376
TD.EQ	Equilibrium personal income tax rate	0.2376
TFP	Total factor productivity	0.8572
TFP.EQ	Equilibrium total factor productivity	0.8572
TW.EQ	Equilibrium total wealth	6.6666
U	Unemployment rate	0.0750
W	Relative wage	0.7016
W.EQ	Equilibrium relative wage	0.7016
X	Exports	0.5020
X.EQ	Equilibrium exports	0.5020
Y	Real output	1.0052
Y.EQ	Equilibrium real output	1.0052
YD	Disposable labour income	0.6181
YD.EQ	Equilibrium disposable labour income	0.6181
YLAB	Labour income	0.6489
YLAB.EQ	Equilibrium labour income	0.6489
YP	Potential output	1.0052
Z	Real exchange rate	1.1200
ZE	Expected real exchange rage	1.1200

	EXOGENOUS VARIABLES	
G	Equilibrium real government expenditures	0.1850
G.eq	Real government expenditures	0.1850
GBTAR	Target federal debt-output ratio	0.5400
GTR	Government net transfers to the public	0.1400
GTR.eq	Equilibrium government net transfers to the public	0.1400
PCDOT	Inflation in the price of consumption goods	0.0100
PCDOTE	Expected inflation in the price of consumption goods	0.0100
PDOT	Inflation in the price of domestic absorption at factor cost	0.0100
PDOTE	Expected inflation in the domestic absorption at factor cost	0.0100
PFCC1	Structural relative-price effect specific to the consumer goods	0.9891
PFCG1	Structural relative-price effect specific to the government goods	1.0200
PFCI1	Structural relative-price effect specific to the investment goods	0.7480
PMROWCAL	International relative price of domestic imports	0.8970
PXROWCAL	International relative price of domestic exports	0.8830
RT.eq	Equilibrium risk premium on borrowed funds	0.0080
RGBP.eq	Equilibrium risk premium on government funds	0.0108
RKP.eq	Equilibrium risk premium on capital	0.0720
RNFAP.eq	Equilibrium risk premium on foreign assets	0.0100
TIC	Inderect Tax on consumption goods	0.1954
TIG	Inderect Tax on government goods and services	0.0300
TII	Inderect Tax on investment goods	0.0800
TK.eq	Direct taxes on corporate profits	0.0750
U.eq1	Equilibrium unemployment rate	0.0750
	MODEL PARAMETERS IN ALPHABETICAL ORDER	
ALPHA	Exponent of capital in Cobb-Douglas production funcion	0.3449
DELTA	Discount factor for consumers	0.9690
DEPR	Rate of depreciation in fractional form	0.0800
FA.SS	Steady-state value of financial assets	1.7200
GAMMA	Probability of death for consumers	0.0400
INV.SS	Steady-state value of investment spending	0.1874
PSI	Fraction of total labour income accrueing to Rule-of-thumb consumers	0.4000
PK.SS	Steady-state value of the price of investment goods	0.8039
QDOT	Growth rate of labour productivity	0.0130

SIGMA	Coefficient of intertemporal substitution for forward-looking consumers	0.5500
TYD	The fraction of government transfers subjected to tax	0.5000
YDOT.EQ	Trend growth rate of real output	0.0380
	MODEL COEFFICIENTS IN ALPHABETICAL ORDER	
CB1	Discount factor in the consumption adjustment equation	0.6000
CD1	Weight on difference 1 in consumption adjustment equation	0.6800
CD2	Weight on difference 2 in consumption adjustment equation	0.1200
CMEQ	Import component of domestic consumption expenditures	0.2190
CV1	Coefficient of the disequilibrium gap of YD in the consumption equation	0.7600
CV2	Coefficient of the disequilibrium gap of RSL in the consumption equation	5.2000
CV3	Coefficient of the disequilibrium gap of NFA in the consumption equation	-0.1200
GMEQ	Import-component of government goods	0.3160
GT1	Coefficient of output gap in disequilibrium government transfer equation	0.2500
IMEQ	Import-component of investment goods	0.4000
KB1	Discount factor in the capital adjustment equation	0.5000
KD1	Weight on difference 1 in the capital adjustment equation	0.8000
KD2	Weight on difference 2 in the capital adjustment equation	0.3000
KV1	Coefficient of the disequilibrium gap of Y in the capital equation	0.8000
KV2	Coefficient of the disequilibrium gap of RSL in the capital equation	1.8300
MPR1	Coefficient of PM.EQ/PFC.EQ in the MPR.EQ equation	0.1050
MPR2	Coefficient of equilibrium PM/PFC gap in the MPR equation	0.0000
MPRB1	Discount factor in the adjustment equation of the MPR equation	0.6000
MPRD1	Weight on difference 1 in the MPR adjustment equation	0.4000
MPRD2	Weight on difference 2 in the MPR adjustment equation	0.2000
PCDE0	Coefficient of PDOTTAR in the equation of PCDOTE	0.2000
PCDE1	Coefficient of PCDOT in the equation of PCDOTE	0.2096
PCDE2	Coefficient of one-period ahead PCDOT in the equation of PCDOTE	0.4202
PCDE3	Weight of endogenous inflation pressures in the equation of PCDOTE	0.1809
PCK1	Coefficient of excess demand pressure in PC equation	0.1200
PCK2	Coefficient of output gap in PC equation	0.2000
PCK3	Coefficient of the disequilibrium gap of PM in the PC equation	0.2600
PCK4	Coefficient of excess inflation in production cost in PC equation	0.0000
PCK5	Coefficient of lagged output gap in PC equation	0.0000
PDE0	Coefficient of PDOTTAR in the equation of PDOTE	0.2000

PDE1	Coefficient of PDOT in the equation of PDOTE	0.2096
PDE2	Coefficient of one-period ahead PDOT in the equation of PDOTE	0.4202
PDE3	Weight of endogenous inflation pressures in the equation of PDOTE	0.1809
PDL1	Coefficient of PDOTE in PDOT equation	0.6200
PDM1	Coefficient of the disequilibrium gap of PM in PDOT equation	0.1433
PDV1	Coefficient of lagged PDOT in PDOT equation	0.4000
PDV2	Coefficient of one-period ahead PDOT in PDOT equation	0.3500
PDX1	Coefficient of the disequilibrium gap of PX in PDOT equation	0.1332
PED	Coefficient of excess demand pressure in PDOT equation	0.2200
PFD1	Weight of expected inflation on PDOT equation	0.1861
PFD2	Weight of distributed lags of inflation in PDOT equation	0.1411
PGK1	Coefficient of disequilibrium gap of PK in PG equation	0.2000
PGK2	Coefficient of disequilibrium gap of PM in PG equation	0.7700
PGK3	Coefficient of disequilibrium gap of the relative wage in PG equation	0.2000
PGY1	Coefficient of output gap in the PG equation	0.1200
PKK1	Coefficient of disequilibrium gap of PM in PK equation	0.3800
PKK2	Coefficient of disequilibrium gap of PM in PG equation	0.4300
PKK3	Coefficient of disequilibrium gap of investment in PK equation	0.8200
PKM1	Coefficient of lagged PI.EQ in PI.EQ equation	0.2000
PKM2	Coefficient of PK.EQ in PI.EQ equation	0.0000
PKM3	Coefficient of PX.EQ in PI.EQ equation	0.8000
PKM4	Coefficient of steady-state gap of investment in PI.EQ equation	0.0000
PKM5	Coefficient of disequilibrium investment gap in PI equation	0.1600
PKM6	Coefficient of the output gap in PI equation	0.0000
PKM7	Coefficient of disequilibrium slope of the yield curve on PI equation	0.4500
PKMY	Coefficient of output gap in the PI equation	0.1200
PKY1	Coefficient of output gap in the PFCI equation	0.1200
PM2	Coefficient of disequilibrium exchange rate in PM equation	0.1300
PM3	Coefficient of lagged relative world price of imports in PM equation	0.1100
PMB1	Discount factor in the PM adjustment equation	0.6000
PMD1	Weight on difference 1 in the PM adjustment equation	0.6500
PMD2	Weight on difference 2 in the PM adjustment equation	0.2800
PME1	Coefficient of lagged PM.EQ in PM.EQ equation	0.5800
PME2	Coefficient of relative world price of imports on PM.EQ equation	0.4200
PX3	Coefficient of disequilibrium real exchange rage gap on PX equation	0.1200
PX4	Coefficient of disequilibrium real exports on PX equation	0.2300
PX5	Coefficient of disequilibrium export gap in PX equation	0.1300
PXB1	Discount factor in the PX adjustment equation	0.4500

PXD1	Weight on difference 1 in the PX adjustment equation	0.2600
PXD2	Weight on difference 2 in the PX adjustment equation	0 1600
PXE1	Coefficient of lagged PX.EQ in PX.EQ equation	0.5200
PXE2	Coefficient of disequilibrium real exchange rate gap in PX.EQ equation	0.4800
PYD	Coefficient of the outptut gap in PDOT equation	0.1150
PYDL	Coefficient of the lagged outptut gap in PDOT equation	0.0800
RL1	Coefficient of R in RL equation	0.8500
RL2	Coefficient of RL.EQ in RL equation	0.1500
RLS1	Coefficient of one-period ahead inflation gap in RSL.EQ equation	1.3900
RT0	The constant term in the equation for the equilibrium term premium.	0.0080
RT1	Coefficient of expected inflation gap equation for the eqilibrium term premium	6.0000
TD0	Coefficient of lagged TD in TD equation	0.2000
TD1	Coefficient of disequilibrium government debt-output ratio in TD equation	0.0300
TDB1	Coefficient of the gap of target government debt-ratio in GB.EQ equation	-0.1250
TDM1	Coefficient of the dummy variable in the GB.EQ equation	0.0120
UB1	Discount factor in the U adjustment equation	0.4600
UD1	Weight on difference 1 in the U adjustment equation	0.2100
UD2	Weight on difference 2 in the U adjustment equation	0.1600
UTRDW	Coefficient of the moving average of equilibrium relative wage in the U.EQ equat	0.0140
UW1	Coefficient of disequilibrium relative wage in U equation	0.4600
UY1	Coefficient of one-period ahead output gap in U equation	0.6000
UY2	Coefficient of two-period ahead output gap in U equation	0.0000
WB1	Discount factor in the relative wage adjustment equation	0.2000
WD1	Weight on difference 1 in the relative wage adjustment equation	0.4000
WD2	Weight on difference 2 in the relative wage adjustment equation	0.2200
WDK1	Coefficient of disequilibrium nominal wage rate in PDOT equation	0.3150
WK1	Coefficient of the wage gap in PDOT equation	0.8800
WSD	The standard deviation of wch in the downward nominal wage rigidity model	4.3500
WV1	Coefficient of disequilibrium unemployment gap in the W equation	0.5600
WV2	Coefficient of disequilibrium price of output at factor cost in W equation	1.0000
WV3	Coefficient of disequilibrium total factor productivity in W equation	0.6800
XB1	Discount factor in the real export adjustment equation	0.8100
XD1	Weight on difference 1 in the real exports adjustment equation	0.4000
XD2	Weight on difference 2 in the real exports adjustment equation	0.2000
XV1	Coefficient of disequilibrium gap of PX in real exports equation	0.0400
XV2	Coefficient of disequilibrium gap of PFC in real exports equation	0.0400
XX2	Coefficient of domestic relative price of exports in X.EQ equation	0.8800

Z1	Coefficient of lagged Z in Z equation	0.0000
Z2	Coefficient of disequilibrium real interest rate in Z equation	0.3800
Ψ	Coefficient of steady-state gap of financial asset in the C.EQ equation	0.6600
ZF1	Coefficient of one-period ahead real exchange rate in ZE equation	0.2000
ZL1	Coefficient of lagged real exchange rate in Z equation	0.3500
	STOCHASTIC SHOCK COEFFICIENTS IN ALPHABETICAL ORDER	
C1CT1	Shock to consumption expenditures due to a contemporaneous shock to potential output.	-0.0278
C1CT2	Shock to consumption expenditures due to a contemporaneous shock to the relative price of exports	-0.0208
C1CT3	Shock to consumption expenditures due to a contemporaneous shock to consumption and investment	-0.0486
C1CT4	Shock to consumption expenditures due to a contemporaneous shock to the relative price of output.	-0.0283
C1CT5	Shock to consumption expenditures due to a contemporaneous shock to the real exchange rate	-0.0283
C1CT6	Shock to consumption expenditures due to a contemporaneous shock to the slope of the yield curve.	-0.0283
C2CT1	Shock to consumption expenditures due to a one-period lagged shock to potential output.	0.0169
C2CT2	Shock to consumption expenditures due to a one-period lagged shock to the relative price of exports	0.0167
C2CT3	Shock to consumption expenditures due to a one-period lagged shock to consumption and investment	0.0134
C2CT4	Shock to consumption expenditures due to a one-period lagged shock to the relative price of output.	0.0269
C2CT5	Shock to consumption expenditures due to a one-period lagged shock to the real exchange rate	0.0055
C2CT6	Shock to consumption expenditures due to a one-period lagged shock to the slope of the yield curve.	0.0344
C1IT1	Shock to investment expenditures due to a contemporaneous shock to potential output.	-0.0070
C1IT2	Shock to investment expenditures due to a contemporaneous shock to the relative price of exports	0.0140
C1IT3	Shock to investment expenditures due to a contemporaneous shock to consumption and investment	-0.0139
C1IT4	Shock to investment expenditures due to a contemporaneous shock to the relative price of output.	0.0064
C1IT5	Shock to investment expenditures due to a contemporaneous shock to the real exchange rate	0.0064
C1IT6	Shock to investment expenditures due to a contemporaneous shock to the slope of the yield curve.	0.0064
C2IT1	Shock to investment expenditures due to a one-period lagged shock to potential output.	-0.0039
C2IT2	Shock to investment expenditures due to a one-period lagged shock to the relative price of exports	-0.0041
C2IT3	Shock to investment expenditures due to a one-period lagged shock to consumption and investment	-0.0074
C2IT4	Shock to investment expenditures due to a one-period lagged shock to the relative price of output.	0.0061
C2IT5	Shock to investment expenditures due to a one-period lagged shock to the real exchange rate	-0.0153
C2IT6	Shock to investment expenditures due to a one-period lagged shock to the slope of the yield curve.	0.0136
C1PYT1	Shock to the relative price of output due to a contemporaneous shock to potential output.	0.0000
C1PYT2	Shock to the relative price of output due to a contemporaneous shock to the relative price of exports	0.0000

C1PYT3	Shock to the relative price of output due to a contemporaneous shock to consumption and investment	0.0000
C1PYT4	Shock to the relative price of output due to a contemporaneous shock to the relative price of output.	0.0000
C1PYT5	Shock to the relative price of output due to a contemporaneous shock to the real exchange rate	0.0000
C1PYT6	Shock to the relative price of output due to a contemporaneous shock to the slope of the yield curve.	0.0000
C2PYT1	Shock to the relative price of output due to a one-period lagged shock to potential output.	0.0000
C2PYT2	Shock to the relative price of output due to a one-period lagged shock to the relative price of exports	0.0000
C2PYT3	Shock to the relative price of output due to a one-period lagged shock to consumption and investment	0.0000
C2PYT4	Shock to the relative price of output due to a one-period lagged shock to the relative price of output.	0.0000
C2PYT5	Shock to the relative price of output due to a one-period lagged shock to the real exchange rate	0.0000
C2PYT6	Shock to the relative price of output due to a one-period lagged shock to the slope of the yield curve.	0.0000
C1RSLT1	Shock to the slope of the yield curve due to a contemporaneous shock to potential output.	0.0071
C1RSLT2	Shock to the slope of the yield curve due to a contemporaneous shock to the relative price of exports	0.0095
C1RSLT3	Shock to the slope of the yield curve due to a contemporaneous shock to consumption and investment	-0.0018
C1RSLT4	Shock to the slope of the yield curve due to a contemporaneous shock to the relative price of output.	0.0012
C1RSLT5	Shock to the slope of the yield curve due to a contemporaneous shock to the real exchange rate	0.0154
C1RSLT6	Shock to the slope of the yield curve due to a contemporaneous shock to the slope of the yield curve.	-0.0044
C2RSLT1	Shock to the slope of the yield curve due to a one-period lagged shock to potential output.	0.0058
C2RSLT2	Shock to the slope of the yield curve due to a one-period lagged shock to the relative price of exports	0.0031
C2RSLT3	Shock to the slope of the yield curve due to a one-period lagged shock to consumption and investment	-0.0002
C2RSLT4	Shock to the slope of the yield curve due to a one-period lagged shock to the relative price of output.	0.0036
C2RSLT5	Shock to the slope of the yield curve due to a one-period lagged shock to the real exchange rate	0.0038
C2RSLT6	Shock to the slope of the yield curve due to a one-period lagged shock to the slope of the yield curve.	0.0020
C1YPT1	Shock to potential output due to a contemporaneous shock to potential output.	-0.0027
C1YPT2	Shock to potential output due to a contemporaneous shock to the relative price of exports	0.0056
C1YPT3	Shock to potential output due to a contemporaneous shock to consumption and investment	0.0056
C1YPT4	Shock to potential output due to a contemporaneous shock to the relative price of output.	0.0056
C1YPT5	Shock to potential output due to a contemporaneous shock to the real exchange rate	0.0056
C1YPT6	Shock to potential output due to a contemporaneous shock to the slope of the yield curve.	0.0056
C2YPT1	Shock to potential output due to a one-period lagged shock to potential output.	-0.0170
C2YPT2	Shock to potential output due to a one-period lagged shock to the relative price of exports	0.0063
C2YPT3	Shock to potential output due to a one-period lagged shock to consumption and investment	0.0063
C2YPT4	Shock to potential output due to a one-period lagged shock to the relative price of output.	0.0063
C2YPT5	Shock to potential output due to a one-period lagged shock to the real exchange rate	0.0063
C2YPT6	Shock to potential output due to a one-period lagged shock to the slope of the yield curve.	0.0063

C1ZT1	Shock to the real exchange rate due to a contemporaneous shock to potential output.	0.0431
C1ZT2	Shock to the real exchange rate due to a contemporaneous shock to the relative price of exports	0.0423
C1ZT3	Shock to the real exchange rate due to a contemporaneous shock to consumption and investment	-0.0344
C1ZT4	Shock to the real exchange rate due to a contemporaneous shock to the relative price of output.	-0.0395
C1ZT5	Shock to the real exchange rate due to a contemporaneous shock to the real exchange rate	-0.0881
C1ZT6	Shock to the real exchange rate due to a contemporaneous shock to the slope of the yield curve.	-0.0436
C2ZT1	Shock to the real exchange rate due to a one-period lagged shock to potential output.	0.0406
C2ZT2	Shock to the real exchange rate due to a one-period lagged shock to the relative price of exports	-0.0410
C2ZT3	Shock to the real exchange rate due to a one-period lagged shock to consumption and investment	-0.0248
C2ZT4	Shock to the real exchange rate due to a one-period lagged shock to the relative price of output.	-0.0342
C2ZT5	Shock to the real exchange rate due to a one-period lagged shock to the real exchange rate	-0.0784
C2ZT6	Shock to the real exchange rate due to a one-period lagged shock to the slope of the yield curve.	-0.0330

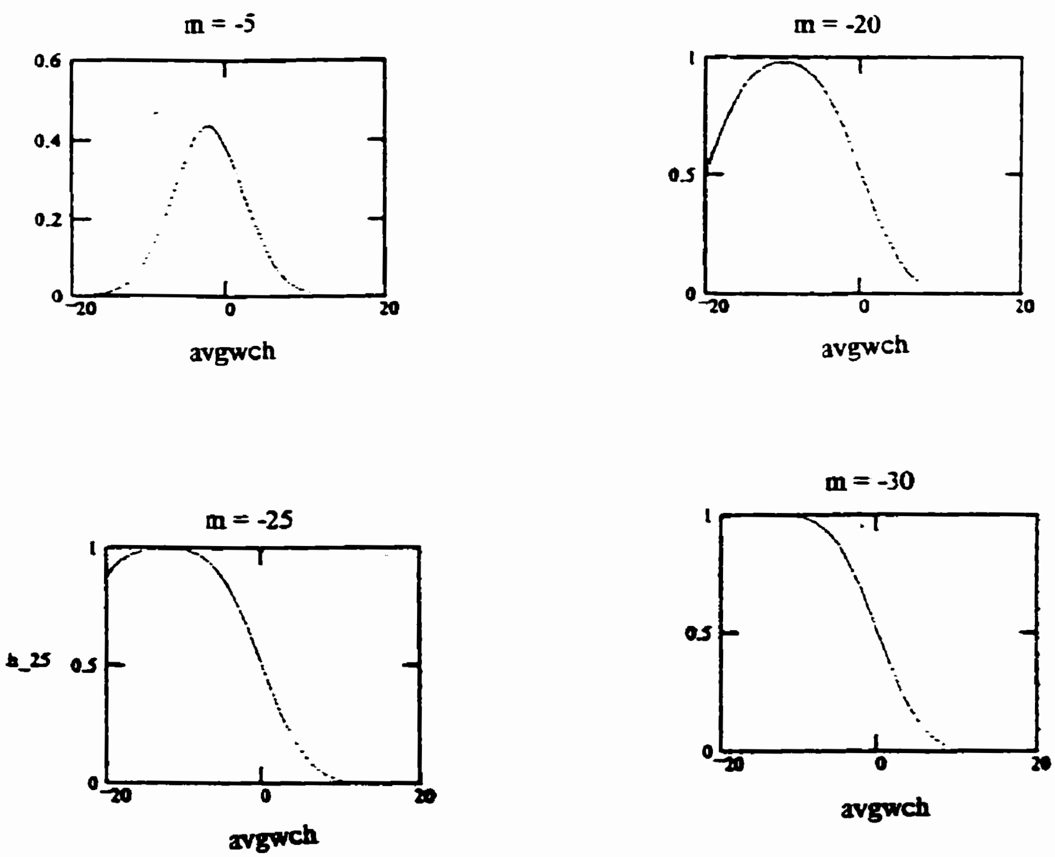
APPENDIX 6: DETERMINING THE FEASIBLE RANGE OF NOMINAL WAGE CUTS USED IN EQUATION (6.3)

THE RANGE OF NOMINAL WAGE CUTS USED IN EQUATION (6.3)

The relevant range of wage cuts, *[m, 0]*, in equation (6.3) is determined outside the model using the normal density function with standard deviation 4.35 and average percentage wage change (*avgwch*) ranging from -20 to 20.[1] Fig 6.1 shows the cumulative probabilities of nominal wage cuts of magnitude zero to ***m*** at each value of ***avgwch***. Fig 6.1 shows that choosing ***m*** to be –30 or lower will include all feasible wage cuts that can result from ***avgwch*** as low as –20%.

Fig 6-1: The cumulative probabilities of nominal wage cuts of magnitude m to zero at each value of ***avgwch***, (***avgwch*** ranging from -20 to 20).

$$cdfwc_j = \int_m^0 dnorm(wch, avgwch_j, wsd)\,dwch$$



[1] Most of the empirical studies quoted in chapter 6 produce percentage change in the base wage within this range.