Optimal Mineral Taxation in Manitoba:

An Exploration of Monte Carlo Simulation Analysis

by

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Abstract

Manitoba has abundant mineral deposits and the mining sector is significant for its economy, especially outside the capital region. This paper examines the Manitoba mining taxation regime, using two approaches. First, a conventional regression analysis is used to estimate the impact of the 2009 mining tax cut on Northern employment and capital investment. This is a general method that assesses how a change in the level of taxation affects these two indicators. This approach potentially offers a general indication of how tax policy influences economic advantages. Unfortunately, data limitations impede the analysis, which leads to an alternative strategy. Second, a mining firm is modelled to directly examine the effect of various tax structures on profitability. A hypothetical underground mine will be modelled using discounted cash flow and net present value methods. Monte Carlo simulation will add a further dimensionality to the analysis, evaluating the effects of taxation when making probability assumptions on metal grade, prices, and operating costs. Of the different tax scenarios, the new mine tax holiday stands out as a significant tax benefit for the miner. Removing it would leave a reasonable profit above the cost of capital for the miner under different tax scenarios, but Monte Carlo simulation showed that the return would reduce the reward substantially and increase risk.

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Dedication

This paper is dedicated to Jennifer Escandón Vega. She has been my motivation throughout this process.

I also dedicate this paper to my family. To my parents, Keith and Susan Verhaeghe, for providing me with the environment to follow my goals and bringing my achievements within reach. To my sister, Stephanie Bianchini, who has always blazed a path to ease my travels.

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Introduction and Purpose

Non-renewable resources attract special attention in the Canadian economy, because they play a crucial role in our national wealth. An economy endowed with natural resources enjoys two important economic advantages:

1. It will receive direct economic benefits in the form of wages and revenues associated with sale of other inputs, and
2. Because natural resources are subject to taxation, public revenues will either support expanded services or reduce the burden of other taxes (income and sales).

How resources are taxed matters. Set the tax too low and public revenues are less than potential. Set the tax too high and the mining operator may cease operation and all benefits vanish. Clearly, an optimum tax exists for every mine in every jurisdiction.

Manitoba has abundant mineral deposits and the mining sector is significant for its economy, especially outside the capital region. This paper examines the Manitoba mining taxation regime, using two approaches. First, a conventional regression analysis is used to estimate the impact of the 2009 mining tax cut on Northern employment and capital investment. This is a general method that assesses how a change in the level of taxation affects these two indicators. This approach potentially offers a general indication of how tax policy influences the first economic advantages. Unfortunately, data limitations impede the analysis, which leads to an alternative strategy. Second, a mining firm is modelled to directly examine the effect of various tax structures on profitability. A hypothetical underground mine will be modelled using discounted cash flow and net present value methods. Monte Carlo simulation will add a further dimensionality to the analysis, evaluating the effects of taxation when making probability assumptions on metal grade, prices, and operating costs.

Chapter 1: Literature Review

Economics of Mining

The economics of mining are defined by several salient characteristics. There is a high degree of uncertainty with respect to future revenue and the present value of projects due to the nature of the industry. Capital is just as mobile in other markets, but the sector's main inputs, the mineral deposits, are immobile. However, the main feature of the mining industry is centred on the fact that resources are finite in supply in the short-run.

The mining industry shares similarities between other capital intensive sectors. While long periods between capital investment and revenue from production are a feature of the sector, significant lag times also exist for other industries, such as utilities. Any project with a large capital investment, such as a new building or factory or installation or upgrade of machinery and equipment, would also have a lag between investment and production. Mining's lag leads to heightened uncertainty due to changes in price and supply factors in global markets.

A mine's life can be estimated to be years or decades, dependent on the estimates of the ore body and other variables, notably mineral prices. Any forecast variable important to the economic feasibility of the mine can change significantly over the life of the mine. Demand could be reduced if a mineral is replaced by a substitutable good. Supply could increase when a new ore body is discovered, which creates downward pressure on prices, again with other things equal. Other changes could be a boon to producers. For instance, new applications of a mineral could increase demand. Or a new technology could reduce the cost of extraction. The theory of resource extraction views the ore body as an asset that should be compared to a financial asset.

Since there is a comparison of physical ore and financial assets, a mine could be viewed as a call option on an asset under finance theory. The call option would be the equivalent of the right to extract the ore at a given price. These extraction costs would be equivalent to the strike price. The option would be exercised when the spot price would exceed the strike price and it would be in-the-money (ITM) ("Strike Price Definition," 2014). That is to say, when the market price of the ore is greater than its extraction costs, the ore would be mined. While the ITM amount would be the intrinsic value of the call option's premium, the other component would be the time value ("Valuation of options," 2014). This would account for uncertainty regarding other influential variables, including but not limited to discoveries, improved extractive technology, increased production, mine closures, changes in supply of substitutes and complements, changes in demand preferences, shifts in political policies, government regulation, and price risk, including speculative risks.

Harold Hotelling compared the price of a non-renewable physical asset such as ore to the growth of the prevailing rate of interest in financial markets, which has come to be known as the "Hotelling Rule".

Hotelling's Rule and the Rate of Interest

Mineral ore deposits in the ground can be extracted in different quantities and paths, and their taxation can impact the economic efficiency of their extraction. With non-renewable resources, and before taxation concerns, the treatment of known ore deposits can be in relation to interest rates. Harold Hotelling's work on resource economics in the thirties is considered seminal. In "The Economics of Exhaustible Resources," Hotelling argued that an owner of minerals would be indifferent between keeping the ore in the ground and extracting it when its price grows at the same rate as the prevailing interest rate (Hotelling, 1931, p. 140). This relation is known as the "Hotelling Rule" (Devarajan & Fisher, 1981, p. 66):

$$p_t = p_o e^{rt}$$

This inter-temporal price relation is emphasized as the primary factor in extraction. Hotelling notes that price "p" is net of costs of bringing the non-renewable mineral to market. This would generally include extraction and marketing costs. If this relation were tilted either way, where the price increased or decreased at a rate other than "r", the optimal path of production would be completely different. That is to say, should the price of the mineral grow at a faster rate than the benchmark interest rate "r" over time "t", then the mineral should be left in the ground and, as an asset, its price will grow with leave the owner with "supernormal capital gains" (Solow, 1974, p. 3). Production will be delayed into the future. If the price of the mineral were to grow more slowly compared to the "r", then it would be optimal to push the production into the present to maximize the present value. This would exhaust the reserves of the mine as soon as possible.

Levhari and Liviatan argue that profit does not grow constantly over time. Rather, marginal profit is decreasing as marginal costs increase with production.

Marginal profit growth may be smaller than r, but there is no other relationship between them. Levhari and Liviatan argue, "it is clear that globally the marginal profit is a decreasing function of time. In this case the rate of growth of marginal profit is not only smaller than r but in fact negative (globally)" (Levhari & Liviatan, 1977, p. 185).

Robert Solow (1974, p. 5) argued that as one mine's life was exhausted, the supply would be restricted and be reflected in higher prices, assuming that this mine were the only source. Supply would reduce demand asymptotically to 0 and the price would theoretically go to infinity. In the bigger picture, Solow saw that low-cost producers would produce ore first and marginal mines would be put into production only as prices rose over time and allowed for the feasibility of these mines to go into production.

Incomplete Exhaustion of a Mine

While Hotelling assumed that exhaustion would be complete, subsequent resource economists relaxed that assumption. Levhari and Liviatan (1977, p. 178) extend Hotelling's model to include complete and incomplete exhaustion of a mine. The objective function remains to maximize present value of the mine's profit. However, the constraints are revised. First, the cumulative production does not need to equal the size of the reserve ($x(T) \leq a$, where **x** is cumulative production, **T** is the terminal point of production in time, and **a** is the size of the reserve).[1] Second, output may or may not be

[1] The terminal point T is determined by the point of exhaustion for Hotelling (1931) and

zero at the terminal point [q(T)≥0, where **q** is current production in time period **t**, and q(t)=d x(t)/dt].

With e^{-rt} as the discount factor given a continuously compounded rate, r, and a cash flow t periods in the future, and π(q) as profit being a function of current output, the maximization equation is as follows:

$$Max \int_{0}^{T} e^{-rt} \pi(q_t) dt$$

Hotelling shows that the optimal extraction is:

$$e^{-rt}\, \partial\pi / \partial q = \lambda,$$

where λ is the Lagrangian multiplier, and using this equation, Levhari and Liviatan (1977, p. 180) show that output is a decreasing function of time. This equality uses the denominator (π”(q) < 0) on the right-hand side to be negative:

$$dq/dt = \lambda r e^{rt} / \pi''(q) < 0$$

The profit function π(q) comprises a revenue function, R(q), less a cost function, C(q). Both of these functions are dependent on current output, q in the Hotelling model (Levhari & Liviatan, 1977, p. 179)**.** Price is assumed to grow according to Hotelling's Rule, but Chapter 3 will test the relation of prices and interest rates on employment and investment. To extend Hotelling's model, Levhari and Liviatan modify the cost function to reflect increasing cumulative production, as well as current production, where **x** is cumulative production as mentioned above.

$$C(q,x)$$

The partial derivative of cost with respect to cumulative production is positive. When the cumulative production increases and approaches its limit of **a**, i.e. the reserve is being depleted, marginal costs rise (1977, p. 180).

$$C_x(q,x) > 0$$

There are two reasons for this negative relationship. First, extraction costs rise as the mine gets deeper and lower grades of ore require more processing as the mine life nears exhaustion make marginal unit costs increase. Second, demand for durables is affected by current stock (or past accumulation) of the resource (Devarajan & Fisher, 1981, p. 69). A large metals inventory creates a market with a surplus, putting downward pressure on the market price, which reflects back to the demand and price of the mineral.

Mining firms are typically price takers in a globally competitive industry. In Manitoba, two nickel mines are owned by a large global conglomerate that could have sufficient market power to influence prices. The ability to store an inventory for sales could provide a "convenience yield" for a mining company that can carry such an inventory compared to those who cannot (Brennan & Schwartz, 1985, p. 139). Scenarios modelled in Chapter 4 assume a perfectly competitive market structure. Other market structures could be developed, however this is not in the scope of this thesis.

In the case of current output being greater than zero at the terminal point, $q(T)>0$, Levhari and Liviatan (1977, pp. 182–183) show that marginal revenue equals marginal cost, and greater amounts of output would incur losses as marginal costs rise. They show that a mine does not need to assume complete exhaustion to extract the maximum amount of ore. Profitability, comprising revenue and cost functions, is the driving factor in determining how much of the ore body to extract.

With the assumption of exhaustion relaxed, the optimal path of production over time may vary in several directions. In contrast to Hotelling's conclusion of decreasing output over time ($dq/dt < 0$) with the case of costs dependent on only current output ($C(q)$), Levhari and Liviatan's model could have current output steady or even increasing up to the terminal point T. In the case of costs as a function of both current and cumulative output ($C(q,x)$), and assuming incomplete exhaustion, output paths can vary in shapes and forms.

Notably, increased interest rates can speed up production. Consequently, this would lower T as production tends towards the present as the higher rate decreases the present value of future production. While cumulative production, $x(T)$, would remain the same, the path to that level would accelerate. A change in r would shift the curve of $x(T)$, which is a shift in $q(t)$. Recall that $q(t) = x'(t)$, so if $x(t)$ is as in Figure 1, then $q'(t)$ could be a straight line decreasing from positive to negative and so $q''(t)$ could be less than zero. Production at any time t en route to T would be greater in the higher rate environment.

$$d\, q_t(t)/dr > 0$$

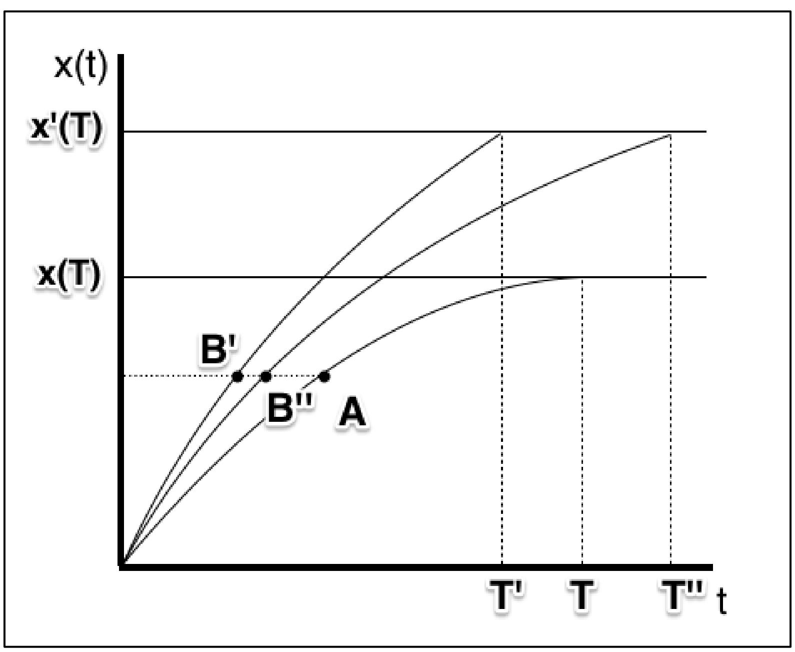
Based on Levhari and Liviatan's work, dq_t/dt could be negative. Current production [$q_t(t)$] could be decreasing in the stylized model and $q_t'(t)$ could be at a decreasing rate. If the optimal path to production was an S-curve, then the first stage of extraction would have a positive d $q_t(t)/dt$, meaning increasing current production over time.

For an increase in demand, reflected by an increase in price, the terminal point T would similarly be accelerated. Any given time t would see more production and T2 < T1 assuming x(T) is unchanged.

$$dT/dp < 0$$

With incomplete exhaustion, where x(T) < a, marginal profit is zero, and marginal cost equals marginal revenue, an upward shift in demand can cause x(T) to go higher. Increased demand can increase cumulative output. A range of outcomes for determining terminal point T exists. It remains unclear if the extraction phase would be prolonged or shortened, as illustrated in Figure 1 (Levhari & Liviatan, 1977, pp. 189–190).

Figure 1: Production Possibilities



Uncertainty with Non-Renewable Resources

Hotelling focused on exploration uncertainty, public rushes into the “commons”, and an inefficient amount of exploration, the latter stemming from the rushes into exploration. There is an element of game theory in exploration among neighbours. Who would drill first? When the first deposit is discovered, neighbouring property owners would free ride that information and begin additional exploration and then extraction. Hotelling thinks that neighbours should not benefit from free riding and the government should appropriate the excess profits on behalf of the public (Devarajan & Fisher, 1981, p. 70).

Succeeding economists divide uncertainty into the supply and demand sides. For supply, depletion is slower when total reserve unknown, so as to avoid shock of zero reserve or depleting the resource when prices might be higher. This is analogous to driving slowly and steadily when there is no gas gauge for a driver. Depletion is similarly conservative (Devarajan & Fisher, 1981, p. 71).

A stable investment climate for all industries is important, but it is particularly so for mining. The time it takes to bring a mine into production from early exploration stages is considerable, often years. Politically, a change of government can often bring with it a change in mining policy. This may outlast the government’s tenure and serves to increase uncertainty. For any business, policy stability over a longer-term outlook is a key factor in investment decisions.

A survey of several multinational mining companies revealed that promising geology is the most important factor behind choosing a potential exploration or mining site among a list of 60 factors. While not surprising *per se*, the other nine reasons in the top ten are related to government policy, be it law or taxation (Otto, 1998, p. 79, n.d., p. 39). These are listed in Table 1. Regulatory and tax regimes are important pieces of any mining site selection.

Table 1: Top 10 Exploration Decision Factors at Exploration Stage

Top 10 Exploration Decision Factors at Exploration Stage
1) Geological potential for target mineral
2) Security of tenure
3) Ability to repatriate profits
4) Consistency and constancy of mineral policies
5) Company has management control
6) Mineral ownership
7) Realistic foreign-exchange regulations
8) Stability of exploration/mining terms
9) Ability to predetermine tax liability
10) Ability to predetermine environmental obligations

Economic Rents

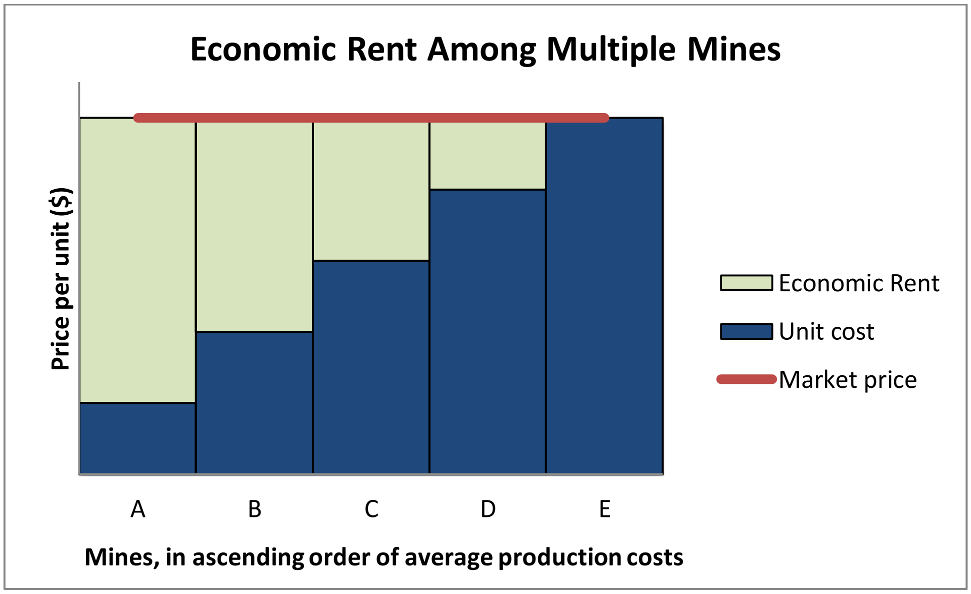
Historically, much of the taxation literature focuses on taxing economic resource rents. Generally, economic rent represents excess profits over what can be considered normal profits for a given investment. Economic rent is the “extra” return from owning an asset that supports above average income. The increased income earned by a star athlete, compared to the income of a journeyman player is a form of economic rent accruing to the “ownership” of that skill. Taxing rent, in theory, does not alter the market equilibrium of supply and demand and therefore remains “neutral”. A tax on economic rent is not a market-distorting means of taxation.

There are issues with rent and its taxation, to be discussed later. But most important is the need for perfect information for the government to ensure it taxes only the rent, and not reduce the normal profit which will surely trigger a cessation in activity.

David Ricardo, a pioneer in the history of economic thought, established the theory of economic “rents” in the nineteenth century. It is based on diminishing marginal productivity of output from additional farms brought into production. The theory states that as an equal amount of capital and labour is brought to farms on different quality of land, ceteris paribus, there will be different yields (Ricardo, 1891, pp. 219–220). The difference in yields leads to a rent that can be charged, which would be equal to the value of the more productive lands less the lowest productive land. While Ricardo used the example of agriculture, he also applied the same logic to mines (1891, pp. 255–256).

Different mines have different yields, and higher yielding sites will command rents over the least profitable mine (earning “normal profit”), as illustrated in Figure 2. The mine of poorest quality will have revenue equal expenditure, such that there are no economic rents. This would be Mine E in the hypothetical case of Figure 2. The other mines would have higher yields with lower average costs and thus provide greater rents. Economic rent to any given deposit would be the difference between total revenue and total expenditures. Costs would include exploration, development, operation and mine rehabilitation. The rent would represent the returns on the “immobile natural resource” (Freebairn & Quiggin, 2010, p. 391).

Figure 2: Economic Rent



While rents are established in relation to mines across Canada and around the world, they are already built into profits, according to the theory. In particular, an optimal mineral taxation policy in Manitoba needs to determine whether if it is, as a province, extracting those rents for public benefit or permitting mining companies to capture those resource rents.

Theory of Mineral Taxation

Capturing the financial benefit of non-renewable resources through taxation policy is an important tool for governments. As Robert McGeorge (1970, p. 157) states, "In order to develop taxation policy for mining operations, taxes must be adapted to the economics of mining." While normal taxation policies of personal and corporate income can accrue some financial benefit to the state, the economics of mining usher in the need to apply different policies to accommodate an industry that has high up-front capital costs, long development times before cash flow turns positive, and an immobile, non-renewable resource. Concomitantly, taxation policy that affects investment incentives will have a secondary impact on production and in turn employment.

There are several types of mineral taxation, according to Garnaut (2010, p. 349) listed below:

1. **Flat fee**: One payment for extraction rights for leased land
2. **Specific or ad valorem royalty (SAVR):** Applied tax on volume or value of production
3. **High rate of proportional profits or income tax:** Same base as income tax, with a higher rate of tax to income received from corporate sector recognizing mineral rent is part of income.
4. **Progressive profits tax:** Uses thresholds and higher tax rates on corporate income levels. When income rises above predetermined thresholds, a higher tax rate is triggered.
5. **Resource Rent Tax (RRT):** A tax on the difference between revenue less all expenses. Financial expenses are excluded, such as interest on debt, because they are a component of return on investment. There is no differentiation between capital and operating costs. The focus is on net cash flow. Negative cash flows are carried forward and scaled up by a rate thought to be expected by the mining company as the return on capital before the project commenced.

6. **Brown Tax (BT):** Same as RRT, though the negative carry-forwards are replaced by payments equal to the tax rate multiplied by the negative cash flow.

The **flat fee** is set competitively through bidding for licences to extract minerals from provincial land. Garnaut (2010, p. 349) suggests that it is more useful in combination with a tax conditional on an outcome, such as level of production, total value, or cash flow.

There are two types of **royalties**, which are taxes on outcomes: specific and ad valorem. Specific royalties levy a tax on volume of production, regardless of prices. Ad valorem royalties are a function of a financial base, such as value of production. While ad valorem royalties would be more sensitive to changes in commodity prices than specific royalties, specific royalties would still be a function of price, depending on the commodity's price elasticity in the production function. Ad valorem taxes increase the lifespan of mine by decreasing the recovery rate.

There are three main problems with royalty regimes for the mining sector. First, royalties are additional variable costs (McGeorge, 1970, pp. 161–162). Any variable cost will raise the cut-off grade to be mined and therefore lower the amount of ore and metal produced (Garnaut, 2010, p. 353). A royalty may discourage extraction in this regard and the financial benefit to the public may never be realized if the mineral remains in the ground. Second, a royalty regime may not keep pace with price gains over time, like an excise tax. In Australia, the effective tax rate fell from about 34% in the early 2000s to about 14% during the subsequent decade. In contrast, economic rent taxes are argued to be more efficient (Freebairn & Quiggin, 2010, p. 387).

The **high rate of proportional profits or income tax** requires recognition that part of the profits or income from the corporate sector is derived from mining rents. Profits and income by industry are not discriminately taxed in Canada. The issue with this tax is that it suffers from the common problem of measuring economic rent.

Garnaut and Anthony Clunies Ross (Garnaut, 2010, p. 350) summarized work on assessing these forms of taxation. Their evaluation was based on stability, neutrality and government revenue maximization. The benefits of stability in a tax regime reduce the uncertainty premium investors charge to allocate capital to mining projects. Stability also has indirect benefits on the other two factors. Stability will contribute to neutrality, which signifies the minimal impact a tax has on production outcomes. Progressively increasing tax rates on higher levels of profits are more stable than other types of taxation. Revenue maximization recognizes that government policy can potentially impact production, and by limiting production, it may not maximize revenue.

Garnaut states that the evaluation favours Resource Rent Tax (RRT) for stability, as well as the Progressive Profits Tax and Brown Tax. For neutrality, Garnaut argues the flat fee and Brown Tax are best, followed closely by RRT. For administration purposes, RRT and the Brown Tax were best as income taxes are revealed to taxation officials (Garnaut, 2010, p. 350).

Property taxes are also suggested as a way for government to benefit from mining (McGeorge, 1970, p. 158), though there are drawbacks to warrant their exclusion. The property can be appraised by land and surface improvements, as well as by the value of the ore deposit. They are at the municipal level and only the area where the property tax was collected would benefit. Since natural resource taxation falls under provincial jurisdiction (*Constitution Act, 1867*, 1867), a tax that concentrates benefits to a comparatively small region of the province would be inconsistent with the principle that benefits should accrue to the province overall.

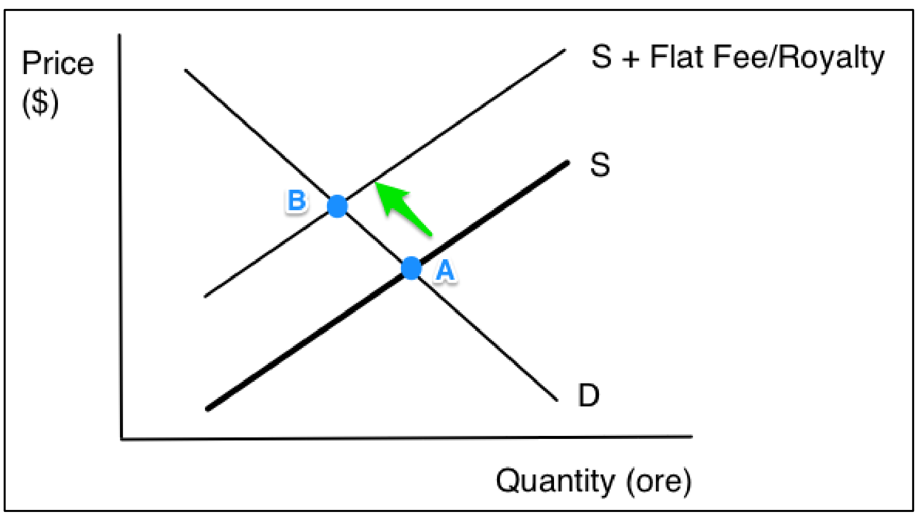
There are other difficulties with property taxes and mining. Valuing an ore deposit is difficult due to uncertain information. Different valuations on the same ore deposit are common and often significantly different. In addition, any property tax will raise fixed costs and lead to a lower recovery level. Production would shift to the present and the mine life would be shortened. While the rate of recovery would increase, the amount recovered would decrease as marginal ore would be left in the ground. The only benefit is that this is a good tax for discouraging speculators (McGeorge, 1970, p. 160).

Economic Rent and Taxation for Metal Resources

Capturing economic rent has been argued as a more efficient method of taxation than a flat fee or royalty regime in the mining sector. However, the difficulty is in its measurement.

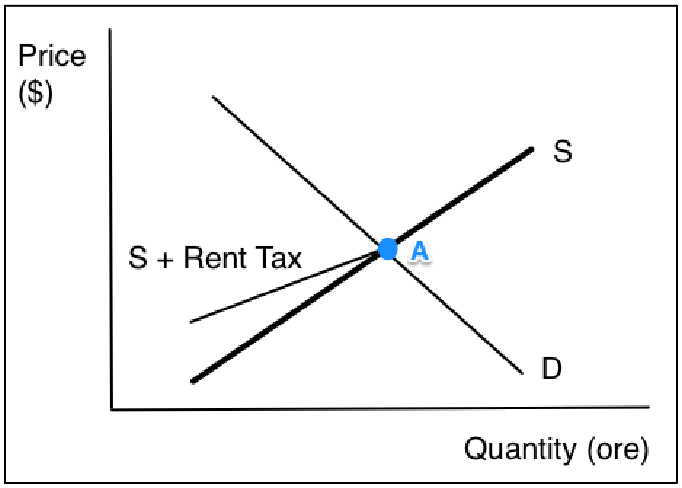
The flat fee adds a fixed cost, while the royalty regime adds a variable cost since it is tied to a benchmark of output, either by value or volume of production. In both cases, the total cost of supply increases, leading to an increase in the cut-off grade for ore. The cut-off grade is the threshold of metals contained in ore required to make the project viable. Below this threshold, the mineral is not economically feasible to extract. The higher cut-off will decrease the total amount of ore produced and mineral extracted. This will leave more of the resource in the ground. Generally, the higher supply curve will result in lower quantity supplied, provided the demand curve is not inelastic (Freebairn & Quiggin, 2010, p. 388; Godoy, 1985, p. 204). In Figure 3, the production of ore moves down from the equilibrium point A to a lower level associated with point B.

Figure 3: Impact of Flat Fee/Royalty on Production



A tax on economic rent would theoretically have no impact on the equilibrium quantity. When normal profits are altered, the resource allocation would be disturbed. At a given price, a tax would take a share of the marginal revenue above the marginal cost. Within that difference would be a component of economic rent on the resource. Increased production would yield more rents for the producer, though at a declining rate due to increasing marginal costs. Production would increase until expenditure equalled revenue. At this point, there would be zero economic rents generated and no tax on rent to remit. This point would be the same under a scenario with no economic rent tax. This is shown in Figure 4, with the equilibrium point A unchanged with a rent tax.

Figure 4: No Impact of Rent Tax on Production



This is the main premise of the economic rent tax over other taxation schemes. While the market production level remains unchanged, “[i]ts principal effect is redistribution of more of the economic rent from the mine operator to government” (Freebairn & Quiggin, 2010, p. 390).

While cash flow is important for any business, capital requirements are intensive for early stage mine development. Progressive taxation could be designed to lower the probability of high profits, but have less impact on lower profit expectations. In tandem with a tax on only profits, the taxation impact would have little effect on marginal projects.

Issues with Economic Rent

While the theoretical arguments to taxation of economic rents are strong, there are several issues with this approach that limits it application. First and foremost, rents must be measured. Administrative issues for government and mining companies impede the calculation of economic rent as a tax base. Second, resource rents must be differentiated from quasi-rents. Third, market neutrality might not be certain.

First, an economic rent tax could be 100% without distorting the market equilibrium quantity and leave the miner with a competitive profit, according to theory. However, recognizing measurement issues with rents creates the case to lower the rate to ensure that the underlying economic activity and consequential benefits continue. From an administrative perspective, segregating activities of vertically integrated operations to define different components of rent is difficult. Mining firms have several activities and are not easily categorized into extraction and production for ease of taxing rents. Returns must be distinguishable on the resource and on the other mining operation elements that go beyond extraction. "It is impossible to isolate distinct 'projects' within such a complex; nor is there any sensible way of allocating *ex post* income to the various stages, much less adequately recompensing mining companies for the substantial risky investment that has been made in the conduct of those operations," (Ergas, Harrison, & Pincus, 2010, p. 371).

Second, recalling that the excess revenue over cost is rent, there could be different components of rent. Rents that are not directly related to the minerals being immobile are "quasi-rents". For instance, there is rent expected from other activities related to mining, such as exploration and development. Investors demand a premium above the normal rate of return for undertaking these activities, which come with accompanying risks (Freebairn & Quiggin, 2010, p. 387). A government may not want to capture quasi-rent if it stifles investment. Quasi-rents could be generated from other market conditions, such as technology, regulation, land ownership, or any other competitive advantage (Garnaut, 2010, pp. 348–349).

Third, the rent tax argument relies on perfect information for the taxation authority on mining revenues and costs to tax the profit (Ergas et al., 2010, pp. 370–371). Since the government is responsible for deciding allowable deductions, anything that is a true cost but not considered deductible will raise the taxable base on a resource rent tax. This could also distort costs, leading to market inefficiencies. By not classifying as many expenses as possible for deductions leads to a taxation regime that does not capture all dimensions of the exploration investment. Thus, without careful application of exemptions, profits-based taxes could discourage investment in resource development.

Resource Rent Tax

The aforementioned reasons suggest that a tax on rent should emphasize consideration to real-world administration issues. The RRT provides stability for investors and mining companies and does not require the government to take on liability for risky projects on behalf of the taxpayer, as in the case of the Brown Tax.

RRT allows deductions of expenses equal to the investment, to ensure that while profits can be made, only the economic rent is taxed. Negative cash flows in early years can be carried forward to future years for later deduction, as well as grossed up by an interest rate. “If the tax base in subsequent years is sufficient to allow complete, effective deduction of the carry-forward, this can ensure that only the rent is taxed,” (Lund, 2009, p. 291).

Deciding which interest rate to use to gross up deductions is part of the government’s uncertainties in applying the RRT. Asymmetric information creates the uncertainty for government, with industry knowing more about the rates of return. Garnaut and Ross argue for different rates of tax on different levels of profit for the RRT to deal with the uncertainty (Lund, 2009, p. 292). Thresholds in taxation according to levels of profit allow RRT to be paid at low rates for projects with low rates of return. Higher RRT rates are triggered by higher rates of return. A progressive system raises the probability of moderate returns and lowers the probability of extremely high returns for companies. The taxing authority can benefit from higher rents through revealed profits by the mining companies. It allows the government to avoid the risk of equity positions and incur absolute losses, yet benefit from the profitability of each project, which can be profitable on different scales (Lund, 2009). It could be added that a progressive tax regime is stable, easy to administer and understand, which facilitates business planning for mining companies.

Summary of Mining Economics and Taxation

The economics of mining are characterized by having an immobile resource in the ground of the province, which is essentially an asset. Hotelling showed that interest rates matter to the rate of production, with an inverse relationship. Levhari and Liviatan argued that a mine does not necessarily completely exhaust a mine’s reserves as the objective function of mining companies is a maximization of profit, not production. Profit is a function of revenue and cost, and the latter two are functions of output. The cost function is increasing with respect to production. There could be production at the end of the mine’s feasible life, as marginal costs could equal marginal revenue and greater amounts of output would result in losses as marginal costs increased.

Underlying the economics of mining, economists agree that government has an important role to play. Taxation can be designed in such a way to tax only economic rent, extract more financial benefit on the public’s behalf, and remain neutral relative to the quantity of metals produced and price signals of market forces with resource rent taxes. In contrast, royalty taxation can impede production, causing permanent losses in production and associated employment and investment.

Chapter 2: Manitoba Mining Sector

Overview and History

Manitoba's mining sector is the second largest primary industry. Its real output (inflation-adjusted) into the economy is over $1.5 billion, representing 2.9% of the Manitoba economy (Statistics Canada, 2014f). It is among the most capital-intensive industries, with 6,300 people employed in the sector representing 1% of the total persons employed in the province in 2013 (Statistics Canada, 2014a). While a small share of the economy and workforce, mining production is an important export. Exports of mineral commodities were 6.6% total foreign merchandise exports in 2013 (Industry Canada, 2014).

In Manitoba, the chief minerals extracted include nickel, copper, zinc, and gold. Most definitions of the mining sector include the growing petroleum sector and, recently, petroleum production has increased its significance. However, as this paper focuses on minerals that fall under the Mining Tax Act, petroleum is excluded from the discussion.

The first mine in Manitoba started producing salt in 1818, long before the province joined Confederation in 1870. Late in the nineteenth century and into the twentieth, coal and lignite were mined in the Turtle Mountain region, in the western part of the province. Early in the twentieth century, gold, gypsum, granite, dolomite, limestone and Tyndall stone were mined and quarried.

Flin Flon mines have been active since 1930 until 2012. Thompson, in the Flin Flon greenstone belt, has been mined primarily for nickel since 1961. Nickel is Manitoba's top metal in terms of both value and volume of production. The mineral-rich Precambrian shield, which contains the greenstone belt, stretches from the northwest to the east and southeast regions of Manitoba. Throughout the province's history, mining has been an important sector for these regions.

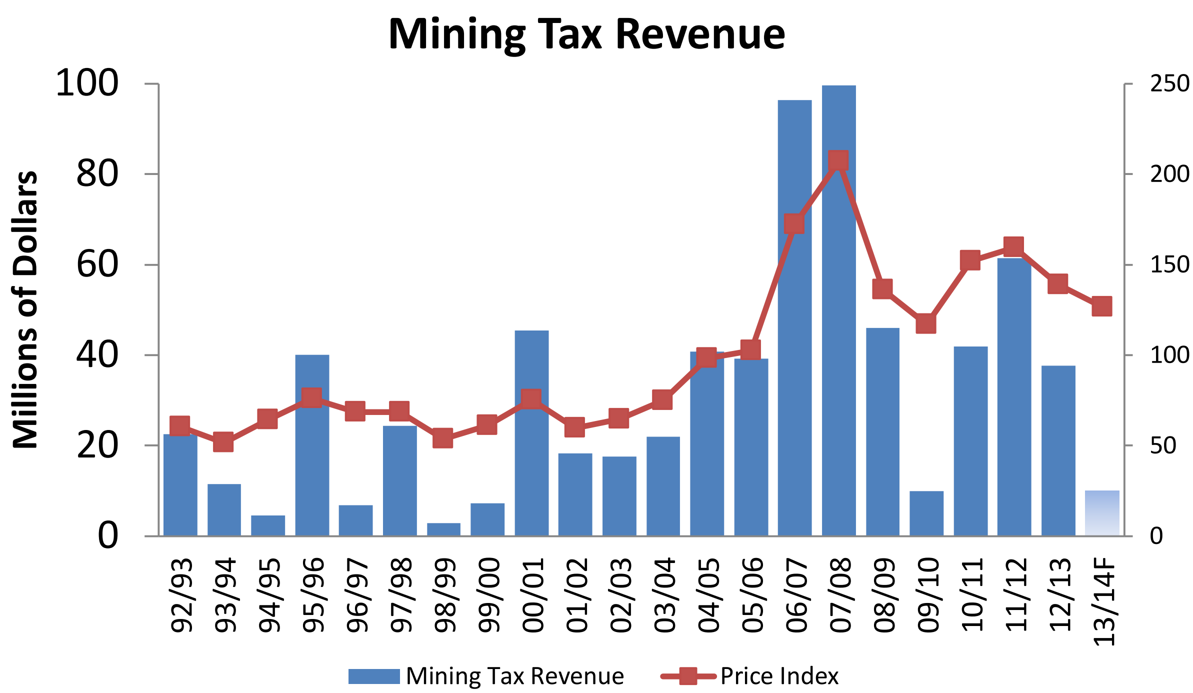
Manitoba Mining Tax Regime

The following section documents the aspects of the Manitoba mining tax and incentive scheme. Generally, this is a variant of the RRT with a profits-based tax and a suite of incentives to offset expenses.

According to the Canadian Constitution, natural resource taxation falls under provincial jurisdiction; i.e. provinces can levy taxes on mineral extraction. This enables analysis based solely on Manitoba taxation and excluding other provinces.

A history of mining tax revenue for the province shows substantial variation, but it is not out of line with the fluctuations in mineral prices. Since 1992/93, the average annual revenue was $33.1 million with a median of $24.3 million. The standard deviation has been high at $27.1 million. In 1998/99, the tax revenue was at its lowest at $2.8 million. In 2007/08, the height of a spike in prices, mining tax revenue generated $99.6 million for the Province of Manitoba. In Figure 5, a price index of Manitoba's major minerals shows a correlation of 0.806 between mining tax revenue and prices over 22 years.[2] The price index is explained in a section of Chapter 3 (Independent Variables).

Figure 5: Mining Tax Revenue and Price Index, 1992-93-2013/14f



f - Forecast, Manitoba Third Quarter Report 2013/14
Source: Manitoba Public Accounts

Mining Tax: A Tax on Profits

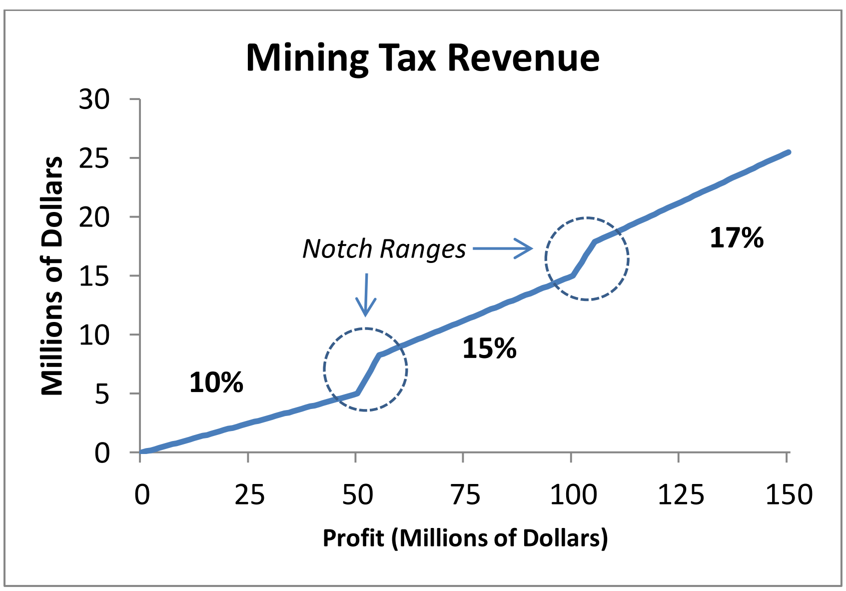
The mining tax is based on profit, i.e. revenue less expense. Previously, it was a flat 18% tax rate. The Government of Manitoba lowered taxes on mining companies by changing the Mining Tax Act in 2009 (“Manitoba Budget 2009,” 2009, p. D9), in the midst of the global recession during which a commodity price boom turned into bust. It was changed to a progressive rate structure with three thresholds with rates of 10%,

[2] The price index is explained in Chapter 3: Data and Methodology and the calculations are explained in Appendix A.

15% and 17% as profits increase. The thresholds are at $50 million, $100 million, and $150 million.

Unlike the personal income tax system, mining tax does not tax different dollars at different rates. Once a new threshold is reached, every taxable dollar is subject to the higher rate. However, protection from the disproportionate increase in the tax liability due to crossing the threshold is eliminated using notch rates. After each threshold, there is a notch rate range. Each range is $5 million. The first range is between $50 million and $55 million. The second range is between $100 million and $105 million. The tax on the first range is 65%, in addition to $5 million. The tax on the second range is 57%, plus $15 million. This allows a miner to keep a share of every dollar of profit generated at all levels of profit and removes a tax measure that would cause a disincentive to production (see Figure 6).

Figure 6: Manitoba Mining Tax Revenue and Rates



Incentives: Credits, Subsidies, and Tax Holidays

There are a number of incentives in place for the mining industry in Manitoba. They are listed here in the order reflecting bringing a mine to production.

Investor Tax Credit

The first incentive aims to raise capital for junior mining companies. On eligible investments, investors qualify for a 15% federal tax credit and a 30% provincial tax credit. Originally a 10% tax credit when it was introduced in Manitoba's 2002 budget, it was increased in two phases in Budget 2009. It was enhanced to 20% in 2009, the same year the mining tax was lowered, and to 30% in 2010 ("Manitoba Budget 2009," 2009, p. D4).

Eligible investments are flow-through shares of qualifying mining exploration companies. Qualifications of the Manitoba credit mirror those of the federal credit, though activity must be within the province. There is also no limit on the amount an individual can invest, and no corresponding limit to the amount an individual can receive as a credit. This is more generous than other tax credits in the province.

Exploration Subsidies

A pair of assistance programs is in place for mining firms for prospecting and exploration. Prospecting is the first stage of geological analysis and exploration is the second, more intensive stage. The Manitoba Prospectors Assistance Program (MPAP) offers up to $10,000 annually to qualifying prospectors ("Incentives: Manitoba Prospectors Assistance Program (MPAP)," n.d.). Prospectors can put it towards eligible expenses, such as wages, food and shelter, transportation, supplies, and services, among others.

The other program is the Mineral Exploration Assistance Program (MEAP). MEAP is intended to support exploration investments through funding 40-50% of eligible expenses up to a limit of $200,000 annually per applicant. Manitoba has allocated $3.0 million for 2014/15 (“Incentives: Mineral Exploration Assistance Program (MEAP),” n.d.).

In addition to these two programs, Manitoba offers mining companies 150% of off-site exploration expenses as a deductible against the mining tax (“Incentives: Mining and Exploration Tax Incentives,” n.d.).

New Mine Tax Holiday

When either a new mine is opened or a closed mine is re-opened, mining firms are eligible for a new mine tax holiday (NMTH). The mining tax is not payable until profits earned equal capital expenses needed to open the mine. At that point, assets are not considered to have depreciated, which operators can advantageously use against taxes in subsequent filings (“Incentives: Mining and Exploration Tax Incentives,” n.d.).

Deductions and Exemptions

In addition to the measures in the preceding section, companies in the mining industry in Manitoba also benefit from a number of deductions from mining tax and exemptions from other taxes (“Incentives: Mining and Exploration Tax Incentives,” n.d.).

In addition to new mines, significant upgrades to existing facilities qualify for the province's processing allowance. This allowance permits mining companies to deduct 20% of the cost of acquired processing assets from mining tax.

Diesel fuel expenses are exempt from the Fuel Tax Act for several mining activities. Specifically, activities include off-site exploration, ore transportation, and ore recovery equipment transportation, all within the province.

Finally, there are several exemptions from retail sales tax (RST). Electricity is exempt from RST in mining, as well as manufacturing in general. Survey and exploration equipment are exempt if brought in on a temporary basis. Prototype equipment for research and development is also RST exempt if temporary.

Next Chapters: Macro and Micro Approaches

In the following chapters, analyses will look at the Manitoba mining sector from two approaches, examining two lines of evidence for the impact of taxes in the Manitoba mining industry. The data will comprise macroeconomic and microeconomic data. In Chapter 3, the public benefit is explored using macroeconomic data. Econometric regressions will evaluate the impact of certain variables on employment, particularly in Northern Manitoba, and capital investment. The last major change in tax policy, a tax cut in 2009, can be evaluated for its efficacy in influencing employment and investment. In Chapter 4, the firm's perspective is analyzed using Monte Carlo simulation. A simulation model will assess the impact of different tax structures on a hypothetical Manitoba mine, which will use microeconomic data and the theory of the firm. It will simulate an underground mine and compare the results of imposing different tax regimes and the effect on internal rates of return of the mining company.

Chapter 3: Taxation on Employment and Investment using Econometric Regression Analysis

This section uses regression to estimate the impact of mining taxes on provincial employment and capital investment in mining. It represents the standard way economics tries to infer an optimum level of mineral taxation. This analysis must work within the bounds of the existing data, and that proves to be an important limitation to this approach.

Data and Methodology

The data will comprise macroeconomic and microeconomic data. This chapter will examine two lines of evidence for the impact of taxes in the Manitoba mining industry. First, it will use econometric regressions with macroeconomic data to evaluate the impact of certain variables on employment, particularly in Northern Manitoba. The last major change in tax policy, a tax cut in 2009, can be evaluated for its efficacy in influencing employment and investment. Second, a simulation model will assess the impact of different tax structures on a hypothetical Manitoba mine, which will use microeconomic data and theory of the firm.

Regression Analysis

Regressions are used to statistically determine if there are relationships among variables as hypothesized. This section will discuss the model specification, data, and analysis of econometric regression analysis. The regressions are calculated in the econometric software EViews.

Model Specification

This paper will set up two econometric regression models, where a dummy variable representing the tax cut of 2009 will be examined after controlling for factors that are external, yet influential to the desired outcome of the tax policy.

The regressions will seek to answer the following questions:

1. What change in **Northern employment** is associated with the tax cut of 2009?
2. What change in **capital investment** is associated with the tax cut?

The dependent variable of the first regression, employment, will focus on the regions with the highest concentration of mines, Parklands and North. Employment in this region was 34,800 in 2013. However, a breakdown by industry is not available at the regional level. This paper uses regional employment as a proxy for mining sector employment. Province-wide, the mining sector directly employs 6,300 people. This paper assumes that the direct employment of mining also has an indirect effect on employment in the immediate area, as other industries provide services incidental to mining. Therefore, indirect employment is used as the dependent variable.

Macroeconomic data include series collected by national agencies at the provincial level for Manitoba, such as metals production from Natural Resources Canada, and capital investment, employment and population from Statistics Canada. Metal prices are obtained from Bloomberg and denominated in Canadian currency.

The employment regression is structured in an ordinary least squares estimation method as follows, with "u" as the residual:

Equation 1

$$\ln(\mathrm{EMPREGION}_t) = \\ \propto + \beta_1 \ln(\mathrm{P}_t) + \beta_2 \ln(\mathrm{P}_{t-12}) + \beta_3 \ln(\mathrm{Q}_t) + \beta_4 \ln(\mathrm{Q}_{t-12}) \\ + \beta_5(\mathrm{INTOVER}_t) + \beta_6(\mathrm{INTOVER}_{t-12}) + \beta_7(\mathrm{INTSPREAD}_t) \\ + \beta_8(\mathrm{INTSPREAD}_{t-12}) + \beta_9 \ln(\mathrm{POPPN}_t) + \beta_{10}(\mathrm{D09}_t) \\ + \beta_{11}(\mathrm{DCLOSURES}_t) + \boldsymbol{\gamma}(\mathbf{DMONTH}) + u_t$$

Table 2 lists the variable, their descriptions, notes and sources.

Table 2: Data and Sources

Data and Sources

Mnemonic	Description	Frequency	Source
EMPREGION	Regional employment for Parklands and North, 3-month moving average	Monthly, Annual	Statistics Canada, CANSIM 282-0054 (monthly), 282-0055 (annual)
INVM	Capital investment in Manitoba mining sector	Annual	Statistics Canada, CANSIM 029-0005
P	Composite index of prices for nickel, copper, zinc, gold and silver	Monthly	Bloomberg
Q	Quantity of Manitoba metals production, Fisher dollars of nickel, copper, zinc, gold and silver	Monthly	Natural Resources Canada
INTOVER	Overnight interest rates	Monthly	Statistics Canada, CANSIM 176-0043
INTSPREAD	Spread between 10-year Government of Canada bond yields and INTOVER	Monthly	Statistics Canada, CANSIM 176-0043
POPPN	Population Parklands and North (aggregate of seven Census Divisions: 16, 17, 19, 20, 21, 22, 23)	Annual	Statistics Canada, CANSIM 051-0036, 051-0052, 051-0062
D09	Dummy variable for tax cut, binary value	Monthly, Annual	Government of Manitoba. In monthly series, 0= before July 2009, 1= July 2009 and after. In annual series, 1= 2009 and after
DCLOSURES	Reflects closures of two mines in H2:2012	Monthly, Annual	HudBay Minerals, Inc. 0= before July 2012, 1= July 2012 and after. In annual series, 0= before 2012, 1= 2012 and 2013
DMONTH	Dummy variable matrix for month, controls for seasonal variation	Monthly	Matrix of 11 series, each a binary variable representing all months except January, which is in the constant term. This is the "policy" variable in the analysis and represents the test of mineral tax impact on the dependent variable.

The first regression has 12-month lags for price, quantity, and interest rates.

The second regression will have capital investment in the Manitoba mining industry as the dependent variable and be structured similarly, albeit the data is available on an annual basis instead of monthly and the seasonal dummy variable matrix is unnecessary. It is structured as follows:

Equation 2

$$\ln(INVM_t) = \propto + \beta_1 \ln(P_t) + \beta_2 \ln(\mathrm{Q}_t) + \beta_3(\mathrm{INTOVER}_t) + \beta_4(\mathrm{INTSPREAD}_t)$$

$$+\beta_5 \ln(\mathrm{POPPN}_t) + \beta_6(\mathrm{D09}_t) + \beta_7(\mathrm{DCLOSURES}_t) + u_t$$

The dependent variables are logged, along with the price index, quantity, and population. The related coefficients then approximate elasticities with respect to each of the logged explanatory variables. This is the sensitivity of the dependent variable with respect to those independent variables (Yang, 2012, p. 4).

Overnight interest rates are subject to a constraint of being between zero and 100%, and are not logged. The spread is at times inverted (negative) and is therefore not logged. Binary dummy variables cannot be logged. For these non-logged variables, multiplying the respective coefficient by 100 approximates the percent change in the dependent variable (Yang, 2012, p. 3).

Hypothesis

Any tax cut should be a boon to economic activity. The tax cut of 2009 ought to increase employment and investment. The coefficient of interest is D09, the tax cut dummy variable. The null hypothesis will test if D09's coefficient is equal to zero and to reject it otherwise in both regressions.

$$H_o: \beta_6 = 0$$

$$H_a: \beta_6 > 0$$

In each regression, if the D09 coefficient β_{10} in Equation 1 and β_6 in Equation 2 is statistically significant and positive, the tax cut will be positively correlated with the dependent variable. A 0.025 critical value as a level of significance is used.

Data Collection

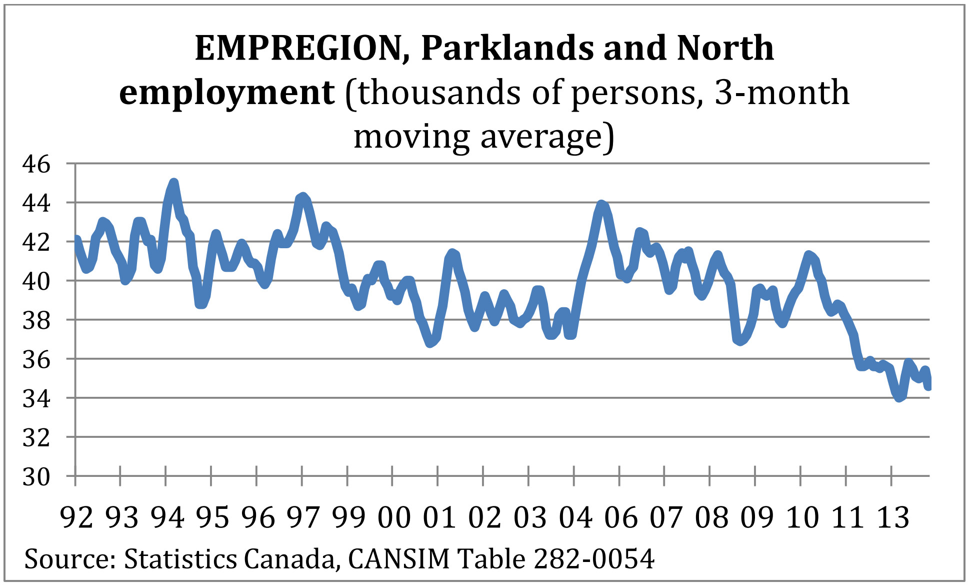
The data come from various sources. This section describes the source of each series and any related special notes. Since the longest time period available for Manitoba mining production of major metals begins in January 1992, the monthly sample size for all variables starts then and ends December 2013. This results in a number of observations of n=264. Annual samples similarly include 1992 to 2013, a sample size of 22. The second regression will suffer from a lack of data points for the dummy tax cut variable.

Dependent Variables

EMPREGION (Regional employment of Parklands and North)

Statistics Canada publishes survey estimates of labour market indicators across Canada through its *Labour Force Survey*. The Manitoba region "Parklands and North" encompasses seven Census Divisions, in which all of Manitoba's active mines are found. The employment data used in this paper are monthly and are reported by Statistics Canada with a three-month moving average (Statistics Canada, 2014b).

Figure 7: Employment, Parklands and North

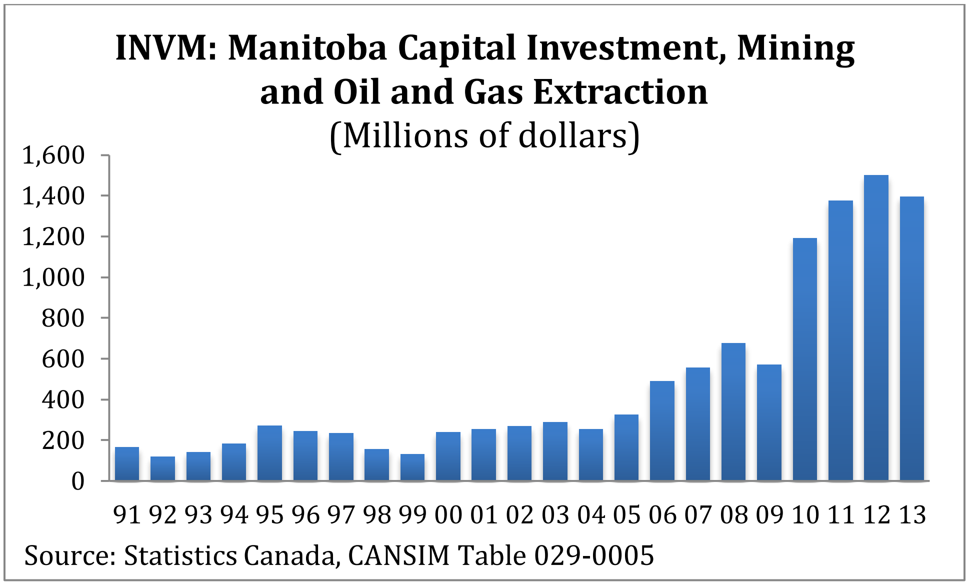


Since employment is presented with a moving average, the following independent variables will also be transformed using a 3-month moving average for the regression Eq (1): price index (P), quantity of production (Q), overnight interest rates (INTOVER) and interest rate spread (INTSPREAD).

INVM (Capital investment in mining, Manitoba)

Statistics Canada publishes an annual survey of private and public investment intentions (Statistics Canada, 2014c). The sample is selected from the Business Register and is compulsory. Subcomponents include industry-level details, with mining among them. Capital expenditure data are submitted for investment intentions for the upcoming year, the preliminary estimates for the previous year, and actual expenditure data for the prior years. The data used in Equation 2 will include a preliminary estimate for 2013, and 1992-2012 will be actual expenditure. Note that the investment figure includes oil and gas extraction, which could send a mixed signal if the distribution between metals mining and oil and gas extraction has changed over time. A separation of the two is not available.

Figure 8: Manitoba Capital Investment in Mining and Oil and Gas Extraction



Independent Variables

P (Weighted price index of Manitoba major metals)

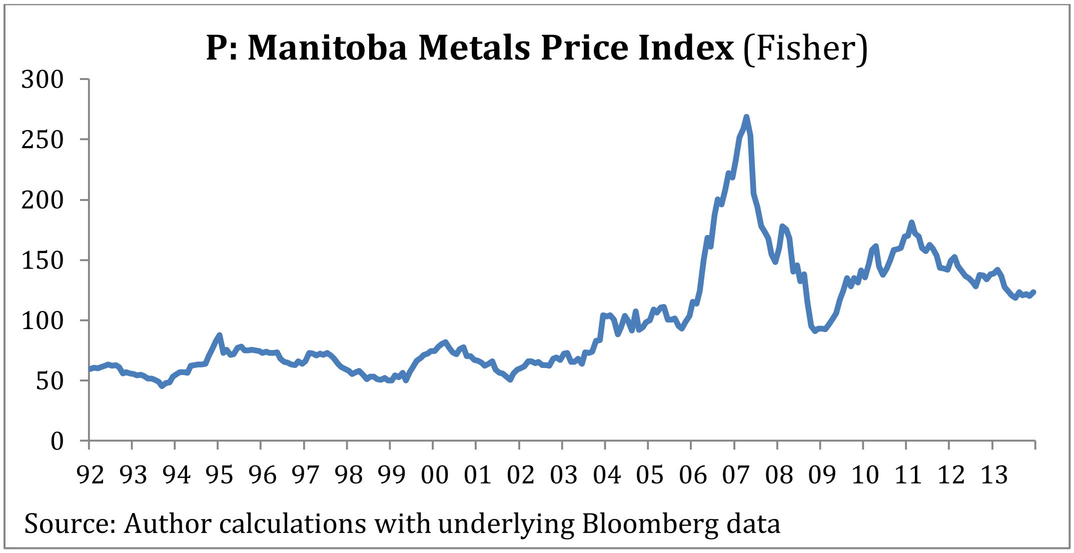
A weighted price index is created to capture the price movements of Manitoba's major metals in a single series. The underlying daily data are from Bloomberg L.P.[3] and are denominated in Canadian currency.

The daily data are averaged by month and the monthly data are averaged by year for the annual series. The Fisher index is used to aggregate the five series. The Paasche and Laspeyres indices allow summation of different commodities, weighted according to importance for Manitoba. The Fisher index reduces the importance of the

[3] The data were obtained by email and permission to use academically was granted via phone.

base year in each of the Paasche and Laspeyres indices by taking the geometric mean of the two (Chevalier, 2013, pp. 1–6).

Figure 9: Price Index



There are two advantages to the single price index. First, from Figure 9, the variation captures the general trend of commodities prices and customizes it for Manitoba. For example, the super-cycle commodity price spike of 2007 and the ensuing bust of the Great Recession of 2008 are clear. This was significant for Manitoba mineral producers. Second, it correlates highly with Manitoba's major metals and weighted appropriately (see Table 3). The price index is over 90% correlated with nickel and copper prices, and 86% correlated with zinc. These base metals comprise 84% of Manitoba's production. Gold is 67% correlated and comprises 15% of production. Silver, just 1% of production, is 71% correlated.

Table 3: Correlation for Prices and Price Index

	Nickel	Copper	Zinc	Gold	Silver		
Correlation for Price Index and Prices	0.956	0.933	0.857	0.673	0.708		
2013 Shares of:	Nickel	Copper	Zinc	Gold	Silver	Base Metals	Precious Metals
Production (%)	52.0	16.2	15.5	15.0	1.3	83.7	16.3
Value (%)	40.4	21.7	14.4	21.4	2.1	76.5	23.5

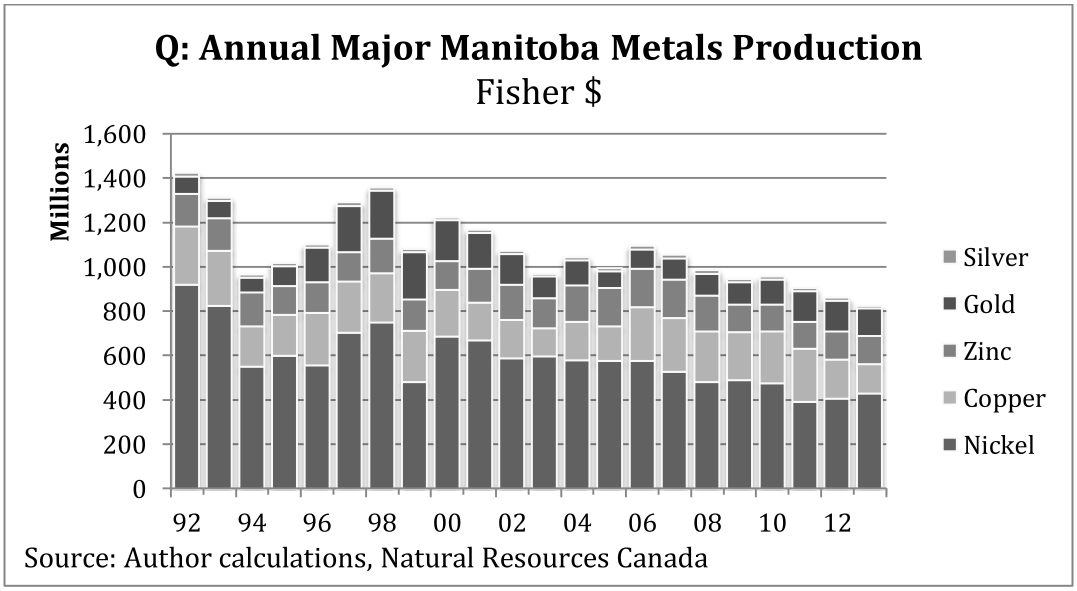
Q (Quantity of Manitoba major minerals, Fisher dollars)

Natural Resources Canada publishes annual mineral production data (Natural Resources Canada, n.d.), and monthly Manitoba data was disclosed to the author[4]. Manitoba mineral production on a monthly basis for nickel, copper, zinc, gold and silver were permitted for use.

The base metals of nickel, copper and zinc are reported in kilogram units, while the precious metals are reported in grams. To aggregate the production, a Fisher calculation is used. Paasche and Laspeyres production dollars are calculated on each based on prices in different base years. The Fisher calculation takes a geometric mean of both to create a dollar sum for all five metals (Chevalier, 2013, pp. 1–6). Figure 10 illustrates a generally downward trend since 1998.

[4] Natural Resources Canada tracks production monthly but it is not published. These data were obtained by email and permission to use here was granted by phone.

Figure 10: Quantity of Production



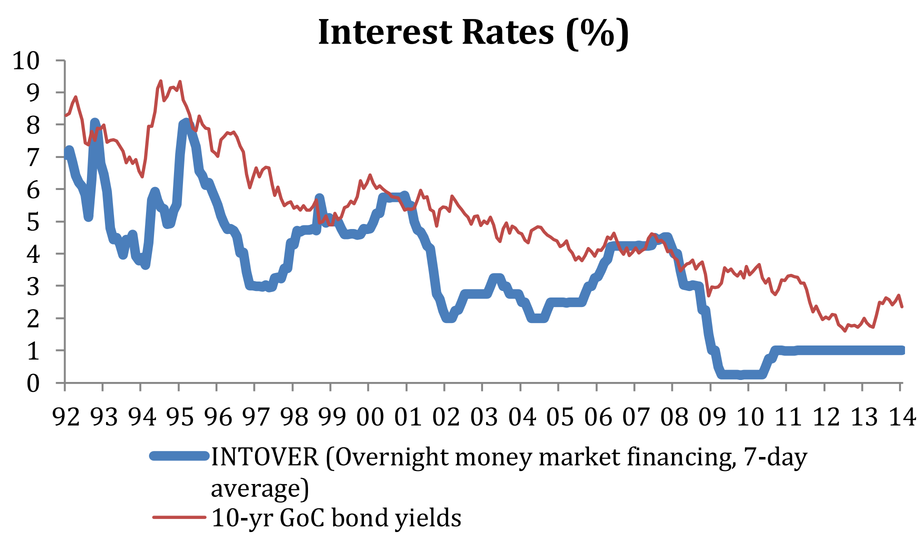
INTOVER and INTSPREAD (Overnight interest rates and Interest rate spread)

From Hotelling's original work, the literature suggests that interest rates were an important factor behind mining extraction. This analysis uses two variables for interest rates: the overnight rate and its spread to the 10-year Government of Canada bond yield (Statistics Canada, 2014h). The overnight rate is the target rate of interest set by the Bank of Canada, also known as the key policy rate. Banks use this rate as a benchmark for setting other rates with respect to risk and maturity. The 10-year bond yield is the rate of interest given for government bonds, the least risky investment. Using two interest rate variables, one at each end of the yield curve, is a good barometer of the state of the financial market. While mining companies will be charged a higher rate from both of these, these variables will serve as a proxy of the state of the financial market. The overnight rate will proxy for high or low interest rate in general. The spread will serve as a proxy for the level of risk perceived in financial markets.

Among the yield curve for government securities, an inverted yield curve (negative spread) for a significant duration of time often precedes a decline in economic activity. A normal, upward-sloping curve is consistent with expectations of economic growth.

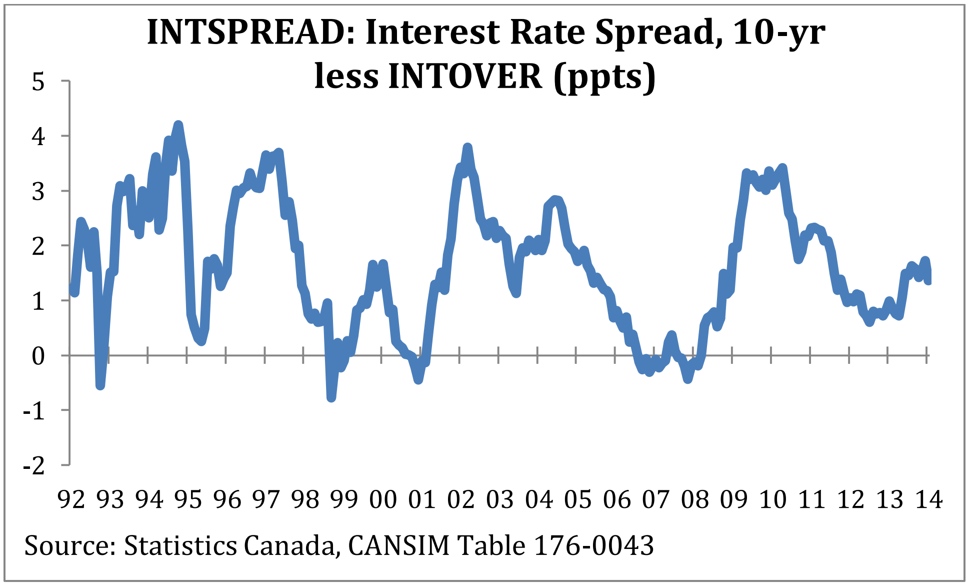
These data are available from Statistics Canada, gathered by the Bank of Canada. These two series are from the same matrix from Statistics Canada and reliably cover the sample period. In Figure 11 and Figure 12, the bold lines are variables in the regression analyses.

Figure 11: Interest Rates



Source: Statistics Canada, CANSIM Table 176-0043

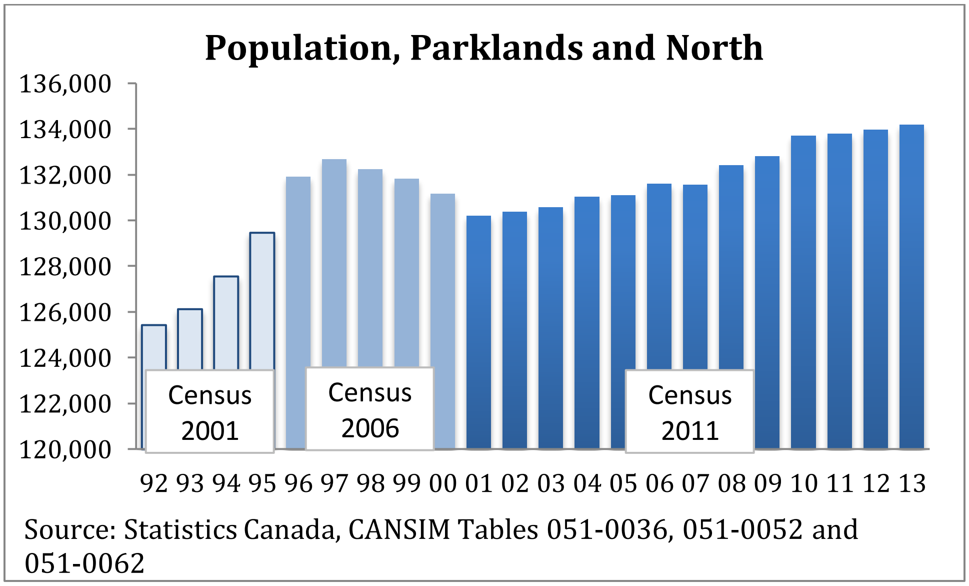
Figure 12: Interest Rate Spread



POPPN (Population of Parklands and North)

The population data are annual and the most recent estimates are taken from three Statistics Canada CANSIM tables to create an uninterrupted time series (Statistics Canada, 2008, 2013, 2014d). The three tables are derived from three different censuses. Census division boundaries have not changed substantially between censuses. Where data overlap, the most recent census figures are taken. The differences between years with overlap are 0.1% or less. The chart below illustrates the population series and its sources.

Figure 13: Population of Parklands and North



For monthly data, EViews software is instructed to create a monthly series from the annual data that is smooth from month to month, yet the annual monthly averages remain equal to the annual value.

D09 (Tax cut of 2009, binary dummy variable)

The tax cut was introduced to support the Manitoba minerals sector, "to maintain the health" of the sector and "ensure that Manitoba's mining tax regime remains competitive" ("Manitoba Budget 2009," 2009, p. D9).

The tax cut following the Great Recession was effective June 11, 2009, according to Manitoba legislation (*The Mining Tax Act*, 2010). A dummy variable to represent the new tax regime was created, where 0 signified the pre-tax change era and 1 represented the post-tax cut era. The time series is a 0 until July 2009, the first full month of the tax change, where it changes to 1 and remains there for the remainder of the series. For the annual series, since half the year is under the new tax regime, 2009 is set equal 1, as well as subsequent years. This means the second regression will have only four data points in the dummy tax variable to gauge the impact of the tax cut.

DCLOSURE (binary dummy variable to control for mine closures)

Hudbay Minerals Inc. closed two mines in the latter half of 2012, reducing its production by 13% that year compared to 2011 and another 20% in 2013. The Trout Lake copper and zinc mine closed June 29, 2012. The Chisel North zinc mine closed in September (HudBay Minerals Inc., 2014b, p. 15). Both mines reached the end of life, as scheduled, where the ore body was depleted to the point where grades were not economic to extract. To control for the closures' effect on the outcome of the regressions, a binary dummy variable DCLOSURE is created. Similar to the D09 tax dummy, DCLOSURE is set to equal 0 before the mid-point of 2012 and set to equal 1 in July 2012 and thereafter. On an annual basis, 2011 and prior is set equal to 0 and 2012 and 2013 are set to 1.

DMONTH (Matrix of seasonal binary dummy variables)

For the regression in Equation 1, which uses monthly data, a matrix of dummy variables is created to control for seasonal fluctuations. For all but one month, a binary dummy variable is created. The effect of the base month is captured in the constant term. Variation in normal annual cycles is controlled in this manner and coefficients of other variables will give better signals. While employment normally increases in the summer, it may be a function of the weather and not other independent variables like price or production. In the regression, there will be eleven variables using the command "@MONTH=X", with X equal to each month of the year except January. With this structure, the coefficients of other months will have either the same or different statistical effects on employment compared to January, the base case month.

Analysis and Results

Regression Eq (1): Regional Employment

Recall Equation 1:

$$
\begin{aligned}
\ln(\mathrm{EMPREGION}_t) = \\
& \propto + \beta_1 \ln(\mathrm{P}_t) + \beta_2 \ln(\mathrm{P}_{t-12}) + \beta_3 \ln(\mathrm{Q}_t) + \beta_4 \ln(\mathrm{Q}_{t-12}) \\
& + \beta_5(\mathrm{INTOVER}_t) + \beta_6(\mathrm{INTOVER}_{t-12}) + \beta_7(\mathrm{INTSPREAD}_t) \\
& + \beta_8(\mathrm{INTSPREAD}_{t-12}) + \beta_9 \ln(\mathrm{POPPN}_t) + \beta_{10}(\mathrm{D09}_t) \\
& + \beta_{11}(\mathrm{DCLOSURES}_t) + \boldsymbol{\gamma}(\mathbf{DMONTH}) + u_t
\end{aligned}
$$

The following table is the output from the econometric software, EViews. Note logs and moving averages are commands executed on the variables. The mnemonics are in **bold** typeface. The 12-month lags are indicated by “**(-12)**”.

Table 4: Equation 1 – Employment

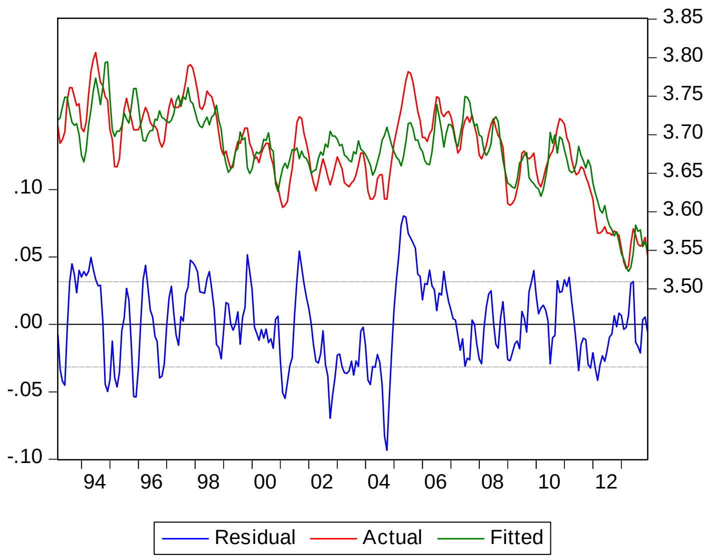
Dependent Variable: LOG(**EMPREGION**)
Method: Least Squares
Date: 04/09/14 Time: 10:20
Sample (adjusted): 1993M03 2013M12
Included observations: 250 after adjustments

Variable	Coefficier	Std. Error	t-Statistic	Prob.
C	-3.502	2.764	-1.267	0.206
LOG(@MOVAV(**P**,3))	0.048	0.011	4.546	0.000
LOG(@MOVAV(**P(-12)**,3))	0.041	0.011	3.810	0.000
LOG(@MOVAV(**Q**,3))	0.083	0.018	4.538	0.000
LOG(@MOVAV(**Q(-12)**,3))	0.121	0.019	6.359	0.000
@MOVAV(**INTOVER**,3)	0.018	0.004	4.958	0.000
@MOVAV(**INTOVER(-12)**,3)	-0.002	0.004	-0.504	0.615
@MOVAV(**INTSPREAD**,3)	0.026	0.004	6.351	0.000
@MOVAV(**INTSPREAD(-12)**,3)	0.014	0.003	4.005	0.000
LOG(**POPPN**)	0.487	0.233	2.094	0.037
D09	-0.043	0.009	-4.762	0.000
DCLOSURES	-0.039	0.011	-3.620	0.000
@MONTH=2	-0.005	0.010	-0.533	0.594
@MONTH=3	-0.020	0.010	-2.035	0.043
@MONTH=4	-0.022	0.010	-2.247	0.026
@MONTH=5	-0.020	0.010	-2.038	0.043
@MONTH=6	-0.001	0.010	-0.051	0.959
@MONTH=7	0.038	0.010	3.792	0.000
@MONTH=8	0.058	0.011	5.441	0.000
@MONTH=9	0.058	0.011	5.367	0.000
@MONTH=10	0.033	0.010	3.336	0.001
@MONTH=11	0.019	0.010	1.946	0.053
@MONTH=12	0.013	0.010	1.345	0.180

R-squared	0.721	Mean dependent va	3.681
Adjusted R-squared	0.694	S.D. dependent var	0.057
S.E. of regression	0.032	Durbin-Watson stat	0.290
Sum squared resid	0.226		
Log likelihood	521.198		
F-statistic	26.676		
Prob(F-statistic)	0.000		

The model performs adequately, with 72.1% of the variation in employment in the Parklands and North region explained by Equation 1, indicated by the R-squared statistic. The high F-statistic indicates the group of variables work well together as a confluence of factors.

Figure 14: Actual vs Fitted Model Eq (1) Results with Residual



An inspection of the residuals, pictured in the Figure 14, shows a distribution around zero, though it has trends within it. The model produces a general worsening result from 2000 to 2004 and cannot explain a spike in 2004/2005. There are other variables that are not explaining the variation in Northern employment. Separate tests for heteroskedasticity and serial correlation reject the hypothesis that the model is free from either (see Table 5 and Table 6). Even the residuals in the 2006-2013 period, which look tightly distributed around zero, have heteroskedasticity and serial correlation, albeit less severe.

Table 5: Equation 1 – Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	**405.636**	**Prob. F(2,225)**	**0.000**
Obs*R-squared	195.719	Prob. Chi-Square(2)	0.000

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Sample: 1993M03 2013M12
Included observations: 250
Presample missing value lagged residuals set to zero.

Variable	Coefficier	Std. Error	t-Statistic	Prob.
C	0.328	1.308	0.251	0.802
LOG(@MOVAV(P,3))	-0.002	0.005	-0.321	0.748
LOG(@MOVAV(P(-12),3))	0.000	0.005	-0.043	0.966
@MOVAV(Q,3)	0.000	0.000	-1.265	0.207
@MOVAV(Q(-12),3)	0.000	0.000	-0.067	0.947
@MOVAV(INTOVER,3)	-0.002	0.002	-0.955	0.340
@MOVAV(INTOVER(-12),3)	0.002	0.002	1.091	0.276
@MOVAV(INTSPREAD,3)	-0.002	0.002	-1.180	0.239
@MOVAV(INTSPREAD(-12),3)	0.002	0.002	1.011	0.313
LOG(POPPN)	-0.026	0.111	-0.237	0.813
D09	0.001	0.004	0.186	0.852
DCLOSURES	-0.001	0.005	-0.197	0.844
@MONTH=2	0.000	0.005	0.101	0.920
@MONTH=3	0.001	0.005	0.181	0.857
@MONTH=4	0.001	0.005	0.172	0.863
@MONTH=5	0.001	0.005	0.246	0.806
@MONTH=6	0.001	0.005	0.168	0.867
@MONTH=7	-0.001	0.005	-0.107	0.915
@MONTH=8	-0.001	0.005	-0.260	0.795
@MONTH=9	-0.001	0.005	-0.289	0.773
@MONTH=10	0.000	0.005	-0.026	0.979
@MONTH=11	0.001	0.005	0.113	0.910
@MONTH=12	0.001	0.005	0.129	0.898
RESID(-1)	1.187	0.062	19.180	0.000
RESID(-2)	-0.374	0.064	-5.882	0.000

R-squared	0.783	Mean dependent var	0.000
Adjusted R-squared	0.760	S.D. dependent var	0.030
S.E. of regression	0.015		
Sum squared resid	0.049		
Log likelihood	712.238		
F-statistic	33.803	Durbin-Watson stat	1.983
Prob(F-statistic)	0.000		

Table 6: Equation 1 – Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	**3.133**	**Prob. F(22,227)**	**0.000**
Obs*R-squared	58.236	Prob. Chi-Square(22)	0.000
Scaled explained SS	44.219	Prob. Chi-Square(22)	0.003

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1993M03 2013M12
Included observations: 250

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.388	0.100	3.886	0.000
LOG(@MOVAV(P,3))	0.000	0.000	0.146	0.884
LOG(@MOVAV(P(-12),3))	0.000	0.000	-0.237	0.813
@MOVAV(Q,3)	0.000	0.000	0.062	0.950
@MOVAV(Q(-12),3)	0.000	0.000	-0.345	0.730
@MOVAV(INTOVER,3)	0.000	0.000	-2.382	0.018
@MOVAV(INTOVER(-12),3)	0.000	0.000	-0.498	0.619
@MOVAV(INTSPREAD,3)	0.000	0.000	-0.808	0.420
@MOVAV(INTSPREAD(-12),3)	0.000	0.000	2.159	0.032
LOG(POPPN)	-0.033	0.008	-3.878	0.000
D09	-0.001	0.000	-3.591	0.000
DCLOSURES	0.000	0.000	0.231	0.818
@MONTH=2	0.000	0.000	0.270	0.788
@MONTH=3	0.000	0.000	0.847	0.398
@MONTH=4	0.000	0.000	1.151	0.251
@MONTH=5	0.000	0.000	1.176	0.241
@MONTH=6	0.000	0.000	0.819	0.414
@MONTH=7	0.000	0.000	0.171	0.864
@MONTH=8	0.000	0.000	0.560	0.576
@MONTH=9	0.001	0.000	1.441	0.151
@MONTH=10	0.001	0.000	2.053	0.041
@MONTH=11	0.001	0.000	1.507	0.133
@MONTH=12	0.000	0.000	0.948	0.344

R-squared	0.233	Mean dependent var	0.001
Adjusted R-squared	0.159	S.D. dependent var	0.001
S.E. of regression	0.001		
Sum squared resid	0.000		
Log likelihood	1354.186		
F-statistic	3.133	Durbin-Watson stat	0.664
Prob(F-statistic)	0.000		

While the model does not capture and explain all variation, it could be explained by a number of factors. An ore body could produce a lower concentration of metals over time or a new mine could improve production with a higher grade, either of which the model is not equipped to control. Other industries may have an effect on the regional employment. Louisiana Pacific, a wood product manufacturer, expanded capacity at its facility ("Annual Reports," 2014). Vale Canada Inc. (formerly INCO, Ltd.) announced a large-scale exploration investment at the time (McNeill, 2005, p. B7). In small sample size regions such as Northern Manitoba, substantial volatility could occur each time Statistics Canada rotates the panel of respondents in its monthly Labour Force Survey, despite the use of a three-month moving average (Statistics Canada, 2014g). All of these factors could explain part or all of the spike, but the model as structured cannot.

Coefficient Analysis of the Tax Cut

The policy variable of interest, D09 as the tax cut, does not perform as expected. The null hypothesis of D09's coefficient as greater than zero is rejected, meaning the tax cut of 2009 is a not significant factor in Northern employment. In fact, the tax cut's effect on employment is negative. While the price index's drop was theorized to capture the effects of the 2009 recession, it may not have captured all of them.

Conclusions and limitations of Regression Eq (1): Regional Employment

The model suffers from omitted variables bias, heteroskedasticity and serial correlation. Omitted variables bias the coefficient estimates. While the presence of heteroskedasticity and serial correlation does not bias the estimates, the variance is not minimized under OLS.

The regression's general results confirmed theoretical expectations in general. Metal prices and quantities of production are positively and significantly correlated with employment in Manitoba's mining regions. Higher interest rates are correlated with increased production. These conclusions held while seasonal cycles and mine closures were controlled in the analysis.

However, the exception of the tax cut's effects on employment was unexpected. The tax cut was found to have a negative effect on employment.

Possibly, the binary dummy could represent other unintended factors. The tax cut's introduction coincided with the Great Recession. Financial markets seized due to a contraction in trust and therefore credit. Central banks globally decreased rates in a coordinated fashion. World demand experienced a downward shock, though this shock was borne out by price signals, which are in the model. The global economy was beginning an unprecedented and prolonged recovery at the same time the dummy variable starts to return a positive value. There could be a myriad of other factors that confuse the tax cut's impact on employment.

The issues with the regression acts in part to justify another approach in modelling optimal mining taxation and its impact on production. Chapter 4 covers a Monte Carlo simulation approach with a hypothetical mine projected with various taxation scenarios.

Regression Eq (2): Capital Investment in Mining

Recall Equation 2:

Eq (2)

$$\ln(INVM_t) = \propto + \beta_1 \ln(P_t) + \beta_2 \ln(\mathrm{Q}_t) + \beta_3(\mathrm{INTOVER}_t)$$

$$+\beta_4(\mathrm{INTSPREAD}_t) + \beta_5 \ln(\mathrm{POPPN}_t) + \beta_6(\mathrm{D09}_t) + \beta_7(\mathrm{DCLOSURES}_t) + u_t$$

With its structure similar to Equation 1, coefficients in Equation 2 also measure elasticity with respect to price, quantity of production and population (β_1, β_2, and β_5 respectively). Interest rates are controlled with INTOVER and INTSPREAD. The variable to evaluate with respect to the tax cut is D09, which has only four data points indicating the tax regime had changed. Mine closures remain controlled with a dummy.

Since this covers the same period, 1992 to 2013, but uses annual data, there are substantially fewer observations (n=22). With seven independent variables, the degrees of freedom of the regression are reduced (d.f. = 22 – 7 = 15).

Table 7 has the econometric regression results for Equation 2 as specified.

Table 7: Equation 2 – Capital Investment

Dependent Variable: LOG(**INVM**)
Method: Least Squares
Date: 03/08/14 Time: 17:30
Sample: 1992 2013
Included observations: 22

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-57.134	60.026	-0.952	0.357
LOG(P)	0.896	0.230	3.891	0.002
LOG(Q)	-0.663	0.611	-1.085	0.296
INTOVER	-0.021	0.065	-0.333	0.744
INTSPREAD	0.005	0.088	0.059	0.954
LOG(POPPN)	5.248	5.028	1.044	0.314
D09	0.534	0.229	2.333	0.035
DCLOSURES	0.371	0.268	1.384	0.188

R-squared	0.938	Mean dependent var	5.868
Adjusted R-squared	0.907	S.D. dependent var	0.798
S.E. of regression	0.244		
Sum squared resid	0.832		
Log likelihood	4.809		
F-statistic	30.124	Durbin-Watson stat	2.222
Prob(F-statistic)	0.000		

Notably, only price index and tax cut coefficients are significant to mining investment in Manitoba. Quantity, interest rates, population and even mining closures are not found to be correlated.

Considering the number of independent variables and the degrees of freedom, it is worth removing some of the irrelevant variables for higher degrees of freedom. This has the added benefit of checking results for robustness of the price and tax cut variables between different model structures.

While removing interest rates and population, but keeping quantity and the closure control, the regression results were robust. Dropping Q and DCLOSURES from the model and leaving only P and D09 changed results slightly, but the signals remained significant and in the same direction.along with selected statistics.

Table 8 compares the original Equation 2 with two versions with fewer variables, along with selected statistics.

Table 8: Robustness of Equation 2 Variations

Comparison of Eq (2) Regressions: Robustness of P and D09
Dependent variable: log(INVM)

Eq (2) Original			*Eq (2a)* No interest rates or POPPN			*Eq (2b)* No Q or DCLOSURES		
∝	-57.134		∝	5.115		∝	5.115	
LOG(P)	**0.896**	*	**LOG(P)**	**0.971**	*	**LOG(P)**	**1.076**	*
LOG(Q)	-0.663		LOG(Q)	-0.849				
INTOVER	-0.021							
INTSPREAD	0.005							
LOG(POPPN)	5.248							
D09	**0.534**	*	**D09**	**0.660**	*	**D09**	**0.937**	*
DCLOSURES	0.371		DCLOSURES	0.367				
n	22		n	22		n	22	
d.f.	15		d.f.	18		d.f.	20	
R-squared	0.938		R-squared	0.927		R-squared	0.898	
F-Stat	30.124	*	F-Stat	54.277	*	F-Stat	83.214	*
Durbin-Watson	2.222		Durbin-Watson	2.117		Durbin-Watson	1.733	

*Significant at 0.05 critical value

First, note that the P and D09 variables are robust among all three equations. The signs do not change and the magnitudes are fairly similar, especially between the first and second regressions.

The second regression, Equation (2a) is the most balanced of the three. Its coefficients are robust compared to the original Equation 2. It keeps with microeconomic theory of prices and quantities, while controlling for the tax cut and mine closures. Its d.f. is higher at 18, though not as high as the third regression. Its F-stat remains significant and the R-squared remains above 0.9, although down slightly from Eq (2). The Durbin-Watson statistic is closest to 2 among the three, signalling the equation is free of serial correlation. The residuals are in line with the original equation, another sign of robustness. Aside from the tax dummy, only prices were significant in the model. With a price elasticity of 0.971, the incentive to invest when prices increase is strong and this result is robust among models.

The third regression, Equation (2b), has highest degrees of freedom, but lowest R-squared and Durbin-Watson statistic. Its coefficients for price and the tax cut are rather extreme. The price cut elasticity is greater than one and the tax cut suggests that a dollar saved is almost a full dollar re-invested, which differs from the more moderate results in the first two regressions. The residuals are slightly more extreme throughout the series, especially in more recent years, such as 2009 and 2013.

Conclusions and limitations of Regression Eq (2): Capital Investment in Mining

Given the comparisons, the best model for capital investment in Manitoba mining is structured as follows:

Eq (2a)

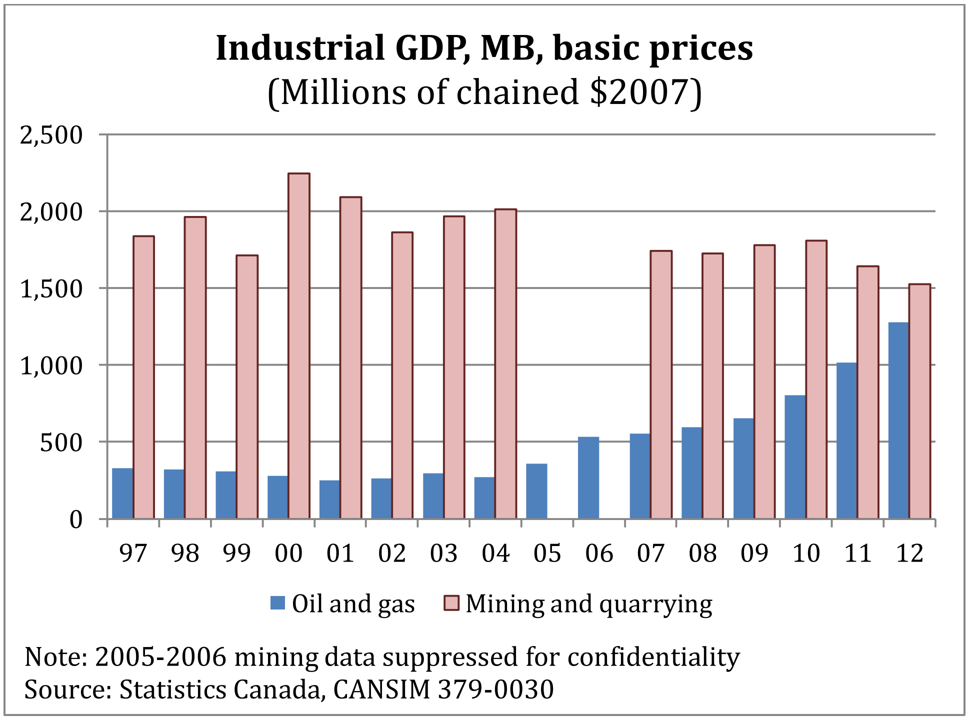
$$\ln(INVM) = \propto + \beta_1 \ln(\mathrm{P}) + \beta_2 \ln(\mathrm{Q}) + \beta_3(\mathrm{D09}) + \beta_4(\mathrm{DCLOSURES}) + u$$

While result of the tax cut in Equation 1 was unexpected with employment, the result with capital investment followed economic theory. A tax cut contributes to increased investment, all other things being equal. With a coefficient of over 0.5 in Eq (2) and higher at 0.660 in Eq (2a), the mining tax cut from a flat 18% on profits to a range of 10% to 17% spurred investment. However, since the D09 variable is binary, the equation can only say that the overall cut was significant, but cannot estimate a dollar-for-dollar impact or elasticity.

The interpretation of the tax cut coefficient must be tempered with the factors that are for and against it. In its favour, the Equation 1 regression had a dependent variable for employment for the Parklands and North region of Manitoba, encompassing all industries. The dependent variable of Equation 2 and Equation 2a is more specific to the industry, as it is the capital investment of the sector in the province. For this reason, the tax cut's effect would seem more reliable of an indicator than it was in the employment model.

However, two points of improvement could be made. First and foremost, more data need to be included in the tax cut dummy. Five observations, from 2009 to 2013 is a small sample size for which to draw conclusions. Second, improvements could be made on investment data. Separation of the oil and gas component of capital investment from mineral extraction would give a clearer signal, as the distribution of capital investment has likely been growing in favour of oil and gas. According to Statistics Canada, the Manitoba oil sector has grown at a faster rate than mining and quarrying since 2004 (both subcomponents of the category Mining, Quarrying and Oil and Gas Extraction; Statistics Canada, 2014f). The data series only cover 1997 to 2012 (Figure 15). For these reasons, an alternative model is worth exploring, and a Monte Carlo model on a hypothetical mine is used for various taxation simulations in Chapter 4.

Figure 15: Manitoba GDP by Industry, Mining and Oil and Gas



Summary

For both regressions, the reduction in mining tax has established a clear correlation to neither regional employment nor capital investment in the mining sector. The tax cut's effects are contrary to theory with a negative correlation to employment. Issues with the variance suggest the model violates assumption of ordinary least squares, including heteroskedasticity and serial correlation.

Investment data lack detail on the minerals sector, with oil and gas data not separated from metals and mining. The proliferation of oil and gas exploration and extraction in Manitoba are a strong signal in the tax cut's occurrence since its growth is coincident with the policy variable. While the tax cut appears to have a positive correlation to capital investment, heteroskedasticity and serial correlation remain present.

Next Chapter: Monte Carlo Simulation Model

The general method of the regression analysis did not lead to adequate conclusions about the change in the tax rate on employment or investment. A correlation of tax policy and its influence on economic outcomes could not be confirmed.

While the macro approach did not yield clear results, another approach potentially offers an indication of how tax policy impacts mining companies: a Monte Carlo simulation of a hypothetical Manitoba mine.

Chapter 4: Monte Carlo Simulation Model

The purpose of the simulation model is to assess the impact of different tax regimes on profitability of a mining company. The modelling approach represents a blend of the purely analytical techniques found in the theoretical literature with empirically grounded relationships. Montel Carlo simulations project profit functions, before and after tax, using probability distributions to explore the range of impacts and identify the most likely outcomes.

The model will be structured similarly to Ugwuegbu's Nigerian gold mine model (Ugwuegbu, 2013), but created to reflect characteristics of a Manitoba mine and with emphasis on the tax implications. Revenue and cost functions will be modelled and separate tax functions will be created to compare different tax structures on the same firm. Uncertainty with respect to metal grades, prices and operating costs will be projected using probabilities.

Model Specification

The simulation model of a typical Manitoba mine is based on assumptions for a modern, underground Manitoba mine. Financial and technical reports of Manitoba mining firms provide reference for creating assumptions. The following table provides an overview of the active and potential mines in the province, as well as recently closed mines, and their companies.

Table 9: Manitoba List of Mines

Manitoba List of Mines

Producing Mines

	Mine	Company	Metals	Production	Type	Census Div
1)	777 in Flin Flon	**HudBay**	Copper, zinc, gold & silver	1.529 million tonnes in 2012 Guidance: 1.620 millions tonnes in 2013	Underground	21
2)	Lalor Lake Deposit	**HudBay**	Gold, copper, zinc & silver	72,293 tonnes in 2012; 418,000 tonnes estimate for 2013 Projected at 1,625,000 t per year in 2018 and later	Underground	21
3)	Reed Lake Deposit	**HudBay (70%)** **VMS Ventures (30%)**	Copper	Expected: 469,000 t/yr over four years starting 2014 Production started Oct 1, 2013	Underground	21
4)	Thompson in Thompson	**Vale Inco**	Nickel	1.160 millions tonnes in 2012	Underground	22
5)	Birchtree in Thompson	**Vale Inco**	Nickel	0.643 million tonnes in 2012, considered for suspension	Underground	22
6)	007 in Bissett	**San Gold**	Gold	San Gold total (all mines):	Underground	19
7)	Rice Lake in Bissett	**San Gold**	Gold	74,277 oz in 2011 & 86,506 oz in 2012, an increase of 16%	Underground	19
8)	The Hinge in Bissett	**San Gold**	Gold	Outlook for 2013: 75,000 to 90,000 oz	Underground	19
9)	Tanco near Bernic Lake	**Tantalum Mining Company of Canada (TANCO)**	Cesium, Tantalum, Lithium	NRCan: suppressed Cesium data for 2011 & 2012 NRCan: 0 Tantalum and 0 Lithium produced in 2011 & 2012	Underground	19

Potential Mines

	Mine	Company	Metals	Production estimates	Type	Census Div
10)	Snow Lake	**QMX Gold** selling to **Liberty Mines**	Gold	Production plan: 80,000 oz/yr, 415,000 oz over five years	Underground	21
11)	Minago near Grand Rapids	**Victory Nickel**	Nickel Frac sand	Projected: 11,000 tonnes/yr concentrated Nickel Projected: 1.1 milion t/yr for ten years of frac sand sales	Open pit	21
12)	Puffy Lake Mine	**Auriga Gold**	Gold	45,000 oz/yr, 7.5 yr mine life, production to start 2013	Hybrid	19

Closed Mines

	Mine	Company	Metals	Production estimates	Type	Census Div
13)	Bucko Lake near Wabowden	**CaNickel** (formerly CrowFlight Minerals)	Nickel	Care and maintenance; 72,256 tonnes in 2012, down from 107,451 tonnes in 2011, both partial years of production	Underground	22
14)	Trout Lake in Flin Flon	**HudBay**	Copper & zinc	248,000 tonnes of ore in 2012 Mine closed June 29, 2012	Underground	19
15)	Chisel North in Snow Lake	**HudBay**	Zinc, copper, gold & silver	187,000 tonnes of ore in 2012 Mine closed September 2012	Underground	19

Sources: Financial reports and regulatory filings of HudBay, Vale, CaNickel, San Gold, QMX Gold, Victory Nickel, VMS Ventures, Auriga
Natural Resources Canada; Statistics Canada

Financial and technical reports for Manitoba mining companies can be used to create estimates for a simulation model. Major mining companies in Manitoba include Vale Canada Ltd. (Vale S.A., 2013), HudBay Minerals Inc. (HudBay Minerals Inc., 2014b), Victory Nickel Ltd. (2010), San Gold Corporation (2013b), Auriga Gold Corporation (Orava et al., 2012), and CaNickel Mining Ltd (2012). With the exception of Victory Nickel's open pit operations, all other mines in the province are underground. Data found in these documents can provide guidance as to what mining companies expect or have experienced for metal concentration in ore, cost of production, cost of capital, etc.

Data and Methodology

Life of Mine: 10 years

The reports are not standardized as each project is unique and at different stages in mine life. At times, data are not available. Where available, data inputs are generally derived from averaging the variables found in the reports. The average life of mine is 12 years among mines where data are available. This excludes three gold mines and the Lalor Lake gold and copper mine due to a lack of data. Notably, it excludes the Thompson nickel mine with a 65-year mine life. Excluding the closed Trout Lake copper and zinc mine and its 30-year mine life, the average falls to nine years. The simulation model assumes a ten-year mine life.

Commodity: Nickel

Since nickel comprised more than half of Manitoba's metals production in 2013 and was the province's largest share of total value of production at 40%, the model uses nickel as the mine's only extractable commodity. Despite the falling production of nickel over the past few decades, exploration for nickel continues in the province's north and nickel prospects remain an important feature of Manitoba's mining future (Naylor, 2014).

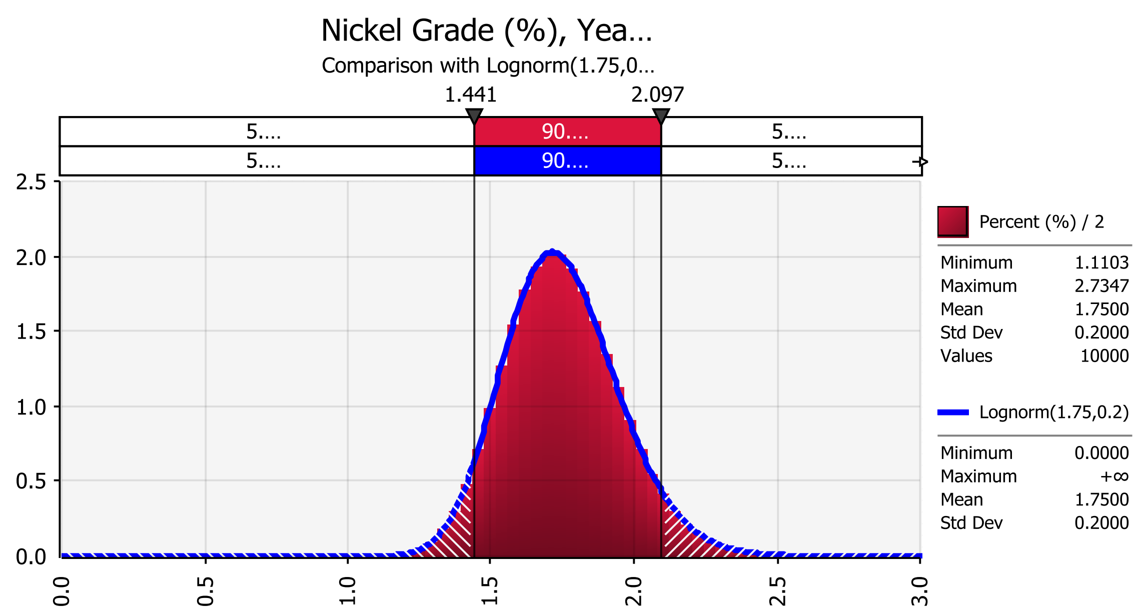
Production Function: Ore, metal grade, and concentrate

The simulation model's production function assumes ore production at a maximum capacity of 648,000 metric tonnes per year. This is in line with Vale's Birchtree nickel mine in Thompson, which is being placed on care and maintenance due to low metal concentration grades. Vale's other nickel mine, the Thompson mine, is larger and its mine life suggests it is atypical.

The production in year 1 is expected to be zero as the mine is being constructed. Year 2 is assumed to be at a quarter of maximum capacity as construction continues and production commences. Years 3-9 assume maximum production and year 10 assumes that production declines to half of the maximum at the end of its mine life. While production could end at some point during the year, the lower level could also compensate for a declining concentration found in the ore at the end of a mine's life, which is not controlled for in the next assumption.

The ore grade for nickel was 1.86% for the Thompson nickel mine and 1.34% for the Birchtree mine in 2012, both owned by Vale. The Bucko Lake nickel mine near Wabowden, at about 1.43% in its reserves, is similar to Birchtree. Birchtree is considered low and the mine is considered for being placed on care and maintenance until prices rise. Bucko Lake is already under care and maintenance. To project a grade with uncertainty, a lognormal distribution is used (Helliwell, 1978, p. 35; Ugwuegbu, 2013, p. 42). The model assumes a 1.75% mean, closer to the Thompson mine grade compared to Birchtree or Bucko Lake. A 0.2 standard deviation keeps the maximum ore grade value under 3%. The following chart shows the distribution of ore grade in year 2 in a simulation with 10,000 iterations. The bars (red) indicate the simulation projection and the line (blue) indicates the lognormal distribution. The distribution parameters are the same for each year.

Figure 16: Nickel Grade Probability Distribution

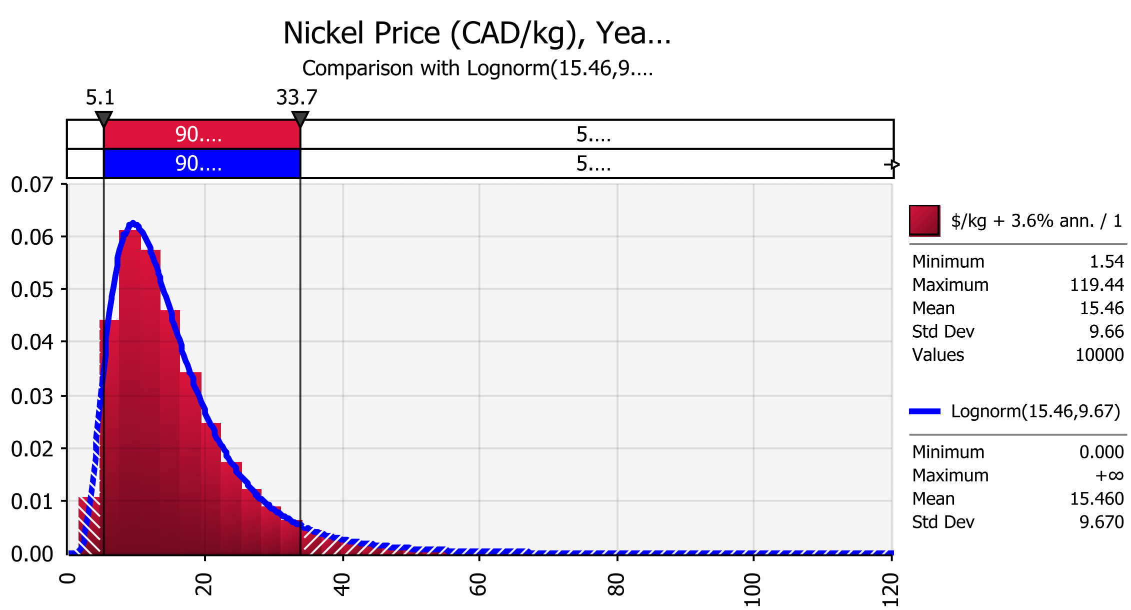


The amount of nickel concentrate is calculated by multiplying ore production by percentage grade, with the product then a variable dependent on uncertainty throughout the projection period.

Revenue Function: Price times quantity

The revenue function is price multiplied by the quantity of nickel concentrate produced, giving total revenue. Price uncertainty is projected using a lognormal probability distribution (Fraser, 2000). The @Risk probability software analyzed the monthly historical data from 1992 to 2013 for metals prices for the best fit of distribution. This is the same dataset as in Chapter 3 and represents the maximum number of observations available. The lognormal distribution is consistently among the best for nickel, copper, zinc and gold. The lognormal distribution is appropriate in capturing the same type of low-probability price spikes seen in commodity markets, as well as being non-negative for prices (Fraser, 2000, p. 220). The mean of the distribution in year 1 is $15.46 per kilogram, the average annual price in 2013 in Canadian currency. Since price is a nominal variable, the mean is escalated by its historical compound annual growth rate over the 1992-2013 period of 3.6%. The standard deviation over history is 9.66, which the software uses to project the price distribution.

Figure 17: Nickel Price Probability Distribution

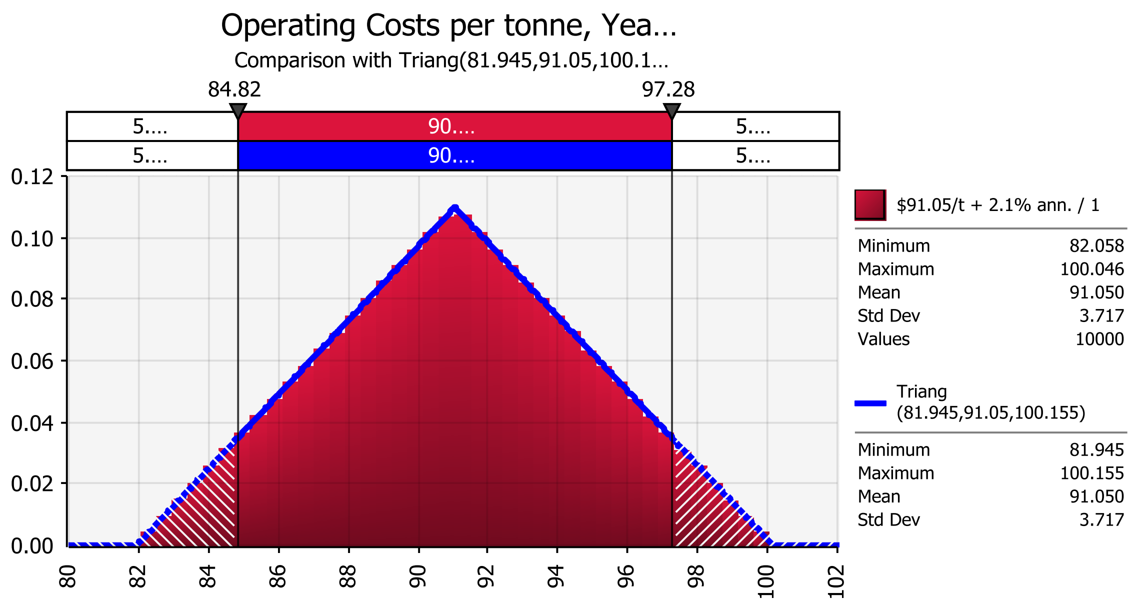


Cost Function: Operating and capital costs

Operating and capital costs are estimated by comparing the reported costs by Manitoba mining companies. Total costs are a sum of both operating and capital costs, and capital costs comprise initial and sustaining capital. Operating, initial capital and sustaining capital costs are based on unit costs multiplied by ore production and summed for total costs.

Operating unit costs are the average of four mining companies that published such data (HudBay, QMX Gold, San Gold and CaNickel), at $91.05 per metric tonne. Though only one of these mines produces nickel, all of them compete for the same labour and face other similar expenses on the costs side. HudBay issued guidance for operating costs for 2013, with a range of ±5% used for its flagship 777 mine and a ±12% for the Lalor Lake mine. While both exceeded the range in 2013, a ±10% range in a triangular distribution is used, as illustrated in the chart below for year 1. Such a distribution is used as a simple range for uncertainty.

Figure 18: Operating Costs Probability Distribution



Operating unit costs are nominal and the mean is escalated by 2.1% annually over the simulation's projection period. The compound average growth rate of 2.1% is the growth of the Industrial Product Price Index from 1992 to 2013 (Statistics Canada, 2014e).

Initial capital costs are projected at $243.30 per tonne and multiplied by the maximum annual capacity of production for total initial capital costs. The mines used in weighted average calculations for capital costs are HudBay's 777 project, Lalor Lake, and its joint project with VMS Ventures at the Reed Lake mine, and QMX Gold's Snow Lake mine. Of other mining companies that published data on capital costs, San Gold and CaNickel were excluded. San Gold's Rice Lake mine was purchased in 2004 after being placed in care and maintenance in 2001. Its capital costs per tonne are unreliably low at less than $10/t. This could reflect a sale at below replacement cost. In addition, there is higher production today than when shares were bought with new deposits of Hinge and 007. CaNickel's Bucko Lake capital costs are a high outlier at $314.29/t, likely a factor in its current care and maintenance status. It is also the only open pit mine, differentiating itself from all other current and recent Manitoba mines, which are underground. The model assumes the hypothetical nickel mine is an underground mine.

A weighted average measures capital unit costs as mines are of varying sizes. Table 10 shows the production and capital costs by unit, along with weighted average and average calculations.

Table 10: Capital Costs and Production

Capital Costs and Production

	Unit Cost ($/t)	Annual Production (millions t)
HudBay	267.67	3.922
QMX Gold	106.73	0.700
CaNickel	314.29	0.350
San Gold	9.68	0.525
WAVG	225.50	
AVG	174.59	
Excluding CaNickel and San Gold:		
WAVG	**243.30**	
AVG	187.20	

Sources for author calculations:
HudBay MD&A 2014,
QMX Gold NI 43-101 Technical Report 2010,
CaNickel NI 43-101 Technical Report 2012,
San Gold NI 43-101 Technical Report 2013

The model sets the proportions of initial capital costs at 50% in year 1, 40% in year 2 and 10% in year 3. This generally follows a similar capital spending profiles published by QMX Gold and Auriga Gold (Orava et al., 2012, p. 94; QMX Gold Corporation, 2010, sec. 18–53).

Mining companies often publish sustaining capital costs, which account for wear and tear of machinery and equipment and maintenance of other assets. Sustaining capital expenses are assumed at 3.5% of initial capital costs starting in year 4 of the mine and continuing until the end of mine life. This is slightly lower than the average of four Manitoba mining firm estimates of 3.9%, but these have substantial variation. While QMX Gold and Victory Nickel have less than 1.0% projected for sustaining capital costs, rough estimates of HudBay are 8.2%, which are certainly overestimated due to lack of data. Auriga Gold is projected at 5.8% on average. Table 11 shows the ratios of sustaining capital to total capital expenditure for the above companies.

Table 11: Sustaining Capital

Sustaining Capital

	% of total capital
Auriga Gold	5.8
HudBay	8.2
QMX Gold	0.9
Victory Nickel	0.5
Average	3.9

Sources for author calculations:
Auriga Gold NI 43-101 Technical Report 2012,
HudBay MD&A 2014,
QMX Gold NI 43-101 Technical Report 2010,
Victory Nickel NI 43-101 Technical Report 2010

Tax Function

There are three components to the tax function: two income taxes for the federal and Manitoba corporate taxes and the Manitoba mining tax that the model will vary to reflect different tax regime scenarios for analysis.

The model can provide counterfactual analysis of what a firm's profits would look like under various tax scenarios. This paper will focus on five mining tax function options. The first three are basic scenarios:

1. no mining tax as a base case,
2. the status quo mining tax regime for Manitoba, which is an RRT with a progressive tax rate (10%, 15% and 17%), and
3. the previous 18% flat tax rate on mining profit, which is an RRT.

Manitoba's New Mining Tax Holiday is included in the second and third scenarios. It will be examined independently to determine their effect on profitability for two additional scenarios.

4. Thresholds, no New Mining Tax Holiday (similar to Scenario 2), and
5. Flat tax, no New Mining Tax Holiday (similar to Scenario 3).

The income tax in the analysis is unchanged and simplified for all the scenarios. *Ceterus paribus*, these tax rates will not change as the model varies the provincial mining tax. The federal and Manitoba CIT rates of 15% and 12%, respectively, are applied directly to positive net income. Depreciation (capital cost allowance) is ignored as the model does not have a breakdown of capital by class according to federal government definitions. Refining this area of the model would serve to decrease the income taxes paid and ultimately increase the NPV. While the effect is not quantified, it is limited to the maximum income tax paid.

These scenarios ignore specific and ad valorem royalties, the taxation on production. The model is not capable of adjusting for the cut-off grade and mine life, which the literature suggests would be the effects of such royalties.

Profit and Tax Functions: Revenue less expense, before and after tax

A before-tax profit function is constructed by subtracting a cost function from a revenue function. An after-tax profit function subtracts a tax function from the before-tax profit function.

Internal Rate of Return (IRR)

At the end of each simulation, a discounted cash flow (DCF) analysis is applied to calculate the NPV of investment to each scenario. The IRR is calculated for both before and after tax. The IRR can be compared to the WACC and the IRR of each scenario simulation. The Monte Carlo simulation is carried out by @Risk software.

The discount rate is calculated using the formula (Ugwuegbu, 2013, p. 41):

$$WACC = R_d(1-T)\left(\frac{D}{E+D}\right) + R_e(\frac{E}{E+D})$$

Where WACC is the weighted average cost of capital, i.e. discount rate, [D/(E+D)] is the share of debt (assumed at 30%) and [E/(E+D)] is the share of equity (70%) (Ugwuegbu, 2013, p. 41), and T is the tax rate at 37%, with corporate income tax of 15% for Canada, 12% for Manitoba (“Manitoba Budget 2014,” 2014, p. C31), and

Manitoba mining tax at 10% (*The Mining Tax Act*, 2010). R_d is the cost of debt, which is 5.94% and the return of equity, R_e, is 11.42%. The WACC is calculated to be 9.11% (Damodaran, 2014).

Analysis and Results

The simulation model runs 10,000 iterations and @Risk software compiles the results and returns probabilities. The model is found on Table 12 on page 76.

Pre-tax model results: Production, revenue, expense and profit

Cumulative **nickel ore production** is over 5 million tonnes. Given the uncertainty modelled around the metal's grade, the mean of **nickel concentrate** is almost 88,000 tonnes at a 1.75% grade and the standard deviation is 3,504 tonnes. The simulation projects a 95% chance that ore grades will lead to 81,178 to 94,891 tonnes of concentrate output.

The mean of **total revenue** over the life of the mine is $1.6 billion with a standard deviation of $314 million. There is a 95% confidence interval between $1.113 billion to $2.339 billion for cumulative revenue. The mean of **total expenditure** is $706 million with a $7 million standard deviation, signifying that 19 times out of 20, the costs will range from $691 million to $720 million. This leaves the miner with **total pre-tax profits** of $929 million as a mean with a standard deviation of $314 million. It has a 95% range of outcomes between $406 million and $1.635 billion. Expectedly for a mine, the first two years run negative cash flow of $112 million cumulatively as construction takes place and production output is much lower than maximum capacity. In year 3, the first of full production, the initial losses are offset with a mean of $111 million of profit.

Those cumulative statistics are nominal, and the projection is reduced to one benchmark with the **internal rate of return (IRR)** indicator. The IRR before tax is 57.9%, an attractive return for investment over the lifetime of the mine. After running the Monte Carlo simulation, the mean IRR is 63.9%, the median is 58.5%, and the standard deviation is 27.6 percentage points. While the worst case scenario would be an IRR of 4.3%, the model does not return a scenario with a negative IRR. This hypothetical mine has a strong case of going forward with production.

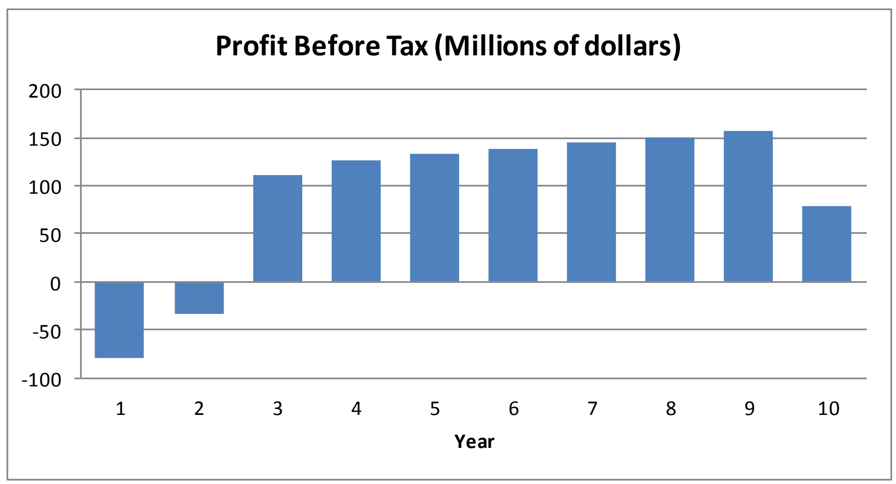
Table 12: Simulation Model

Underground Manitoba Nickel Mine	**Units/Notes**	Year										
		1	2	3	4	5	6	7	8	9	10	Cumulative
Production Function												
Ore Production	000 metric tonnes	0	162	648	648	648	648	648	648	648	324	5,022
Grade	Percent (%)	0.00	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	
Nickel concentrate	Metric tonnes	0	2,835	11,340	11,340	11,340	11,340	11,340	11,340	11,340	5,670	87,885
Revenue Function												
Historical CAGR (92-13) of Price Index	3.6%											
Price	$/kg + 3.6% ann.	15.46	16.02	16.59	17.19	17.81	18.45	19.11	19.80	20.52	21.25	
Total Revenue	**$000**	**0**	**45,407**	**188,166**	**194,940**	**201,958**	**209,229**	**216,761**	**224,564**	**232,649**	**120,512**	**1,634,187**
Cost Function	c'(volume)>0											
Historical CAGR (92-13) of IPPI* (%)	2.1%											
Operating costs per tonne	$91.05/t + 2.1% ann.	91.05	92.96	94.91	96.91	98.94	101.02	103.14	105.31	107.52	109.78	
Operating costs	$000	0	15,060	61,504	62,796	64,115	65,461	66,836	68,239	69,672	35,568	**509,252**
Initial capital cost	$000 ($243/t of max prod'n)	157,658										
Initial distribution	1=100%	0.5	0.4	0.1								
Sustaining capital	3.5% of Initial K/yr				0.035	0.035	0.035	0.035	0.035	0.035	0.035	
Capital costs	$000	78,829	63,063	15,766	5,518	5,518	5,518	5,518	5,518	5,518	5,518	196,285
Total Cost	**$000**	**78,829**	**78,123**	**77,270**	**68,314**	**69,633**	**70,979**	**72,354**	**73,757**	**75,190**	**41,086**	**705,536**
Profit Function, ex-ante tax												
Before Tax	$000	-78,829	-32,716	110,896	126,626	132,325	138,250	144,407	150,807	157,458	79,426	**928,650**

*IPPI: Industrial Product Price Index

Blue indicates @Risk probability input

Yellow indicates @Risk output



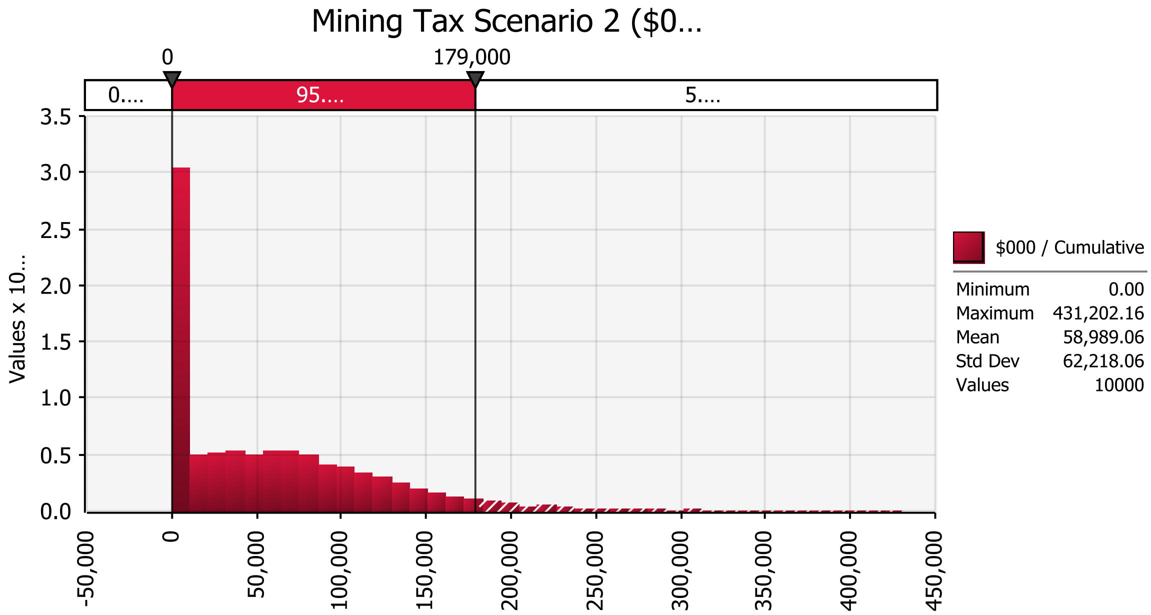
Scenario 1: No mining tax

After applying only federal and Manitoba corporate income tax, the model's IRR drops from 57.9% to 43.6%. After running the simulation, the mean IRR is 48.7% with a 21.7 standard deviation. Compared to the WACC of 9.1% and after income tax, this remains a case with optimistic fundamentals. Though there is difficulty in measuring economic resource rent, a large return is theoretically reflective of large rent component. The immobility and scarcity of the resource in the ground, as well as other rent factors, such as exploration investment or technology serve to increase the overall profit.

Scenario 2: Status Quo tax regime

The status quo tax regime includes progressive tax structure of the Manitoba mining tax and the New Mine Tax Holiday (NMTH). Scenario 2, compared with Scenario 1, lowers the overall IRR slightly, to 43.1%. The simulation mean IRR is 47.5% with a standard deviation of 20.5. While layering the tax rates of 10%, 15% and 17% with respective thresholds, the mining tax yields a mean of $58.9 million and a median of $44.4 million. Due to the limit of the tax being greater than zero, the distribution is not even. There is a 32% probability that the mining tax will yield between zero and $10 million.

Figure 19: Mining Tax Distribution



The mining tax calculations before the NMTH deductions have a mean of $171.5 million, with a standard deviation of $55.1 million. The impact of the NMTH is large. While ignoring probability output, the model shows that mining tax does not exceed the New Mining Tax Holiday until year 8 of the ten-year life of mine.

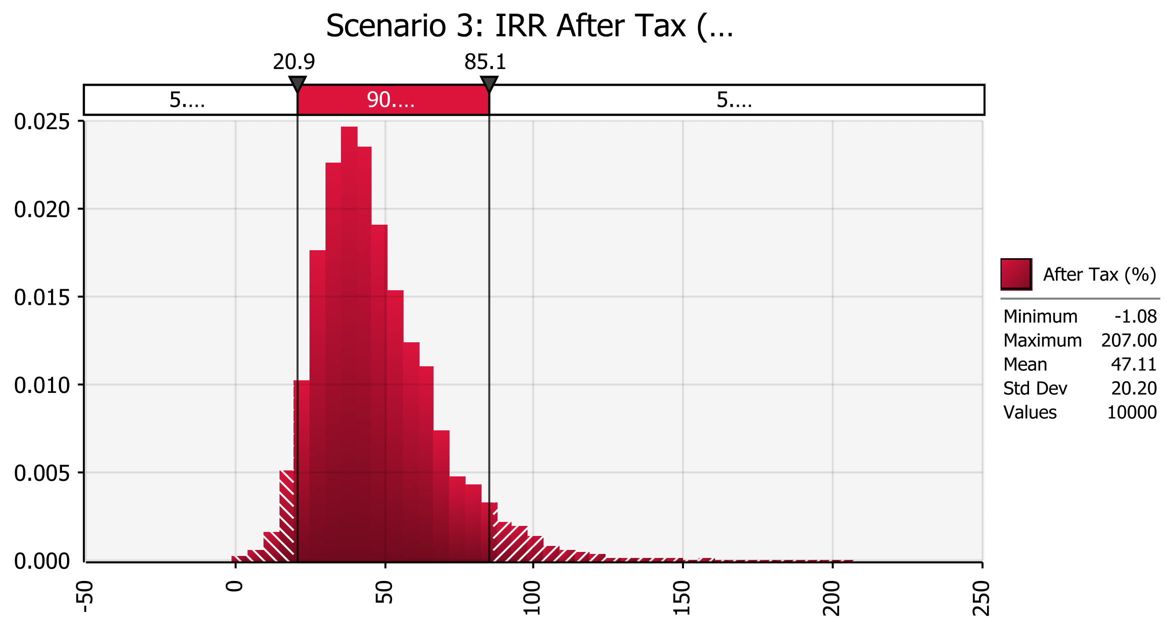
Note the simulation model results in over $100 million of profit annually in all years with full production, triggering the 17% mining tax rate. This means that differences with the flat tax scenario will be smaller than if the mine generating smaller profits and triggering lower tax rates.

Scenario 3: Flat Tax

The flat tax yields an IRR of 42.9%, similar to the IRRs of the previous scenarios. Before introducing uncertainty, the 18% flat tax scenario generates $13.5 million more in nominal tax revenue than the Status Quo scenario, or 31%. The increase comes from the higher rate and the higher rate driving the mining tax revenue over the NMTH greater than in the Status Quo scenario, but still in year 8.

After running the simulation, the IRR mean is 47.1% with a standard deviation of 20.2 percentage points.

Figure 20: IRR Probability Distribution



Scenario 4: Thresholds, No New Mining Tax Holiday

Using the Status Quo structure and removing the NMTH, cumulative mining tax revenue increases to $175 million from $43 million before running the model. Under the Status Quo, mining taxes were not collected until year 8. In this scenario, mining tax remittances commence in year 3. The IRR remains profitable at 33.4% compared to the WACC of 9.1%.

After running the model, the IRR mean is 38.2% with a standard deviation of 17.8 percentage points. There is a 99.9% probability of positive returns. The project remains profitable despite removing a tax advantage for the mine.

Scenario 5: Flat tax, No New Mining Tax Holiday

Using the flat tax structure and again removing the NMTH, the cumulative mining tax revenue increases to a mean of $188.7 million, or 6.8%, compared to the previous scenario mean using thresholds. Mining tax is also collected in year 3 and onwards. The IRR before uncertainty is 32.7%, slightly below the 33.4% of Scenario 4.

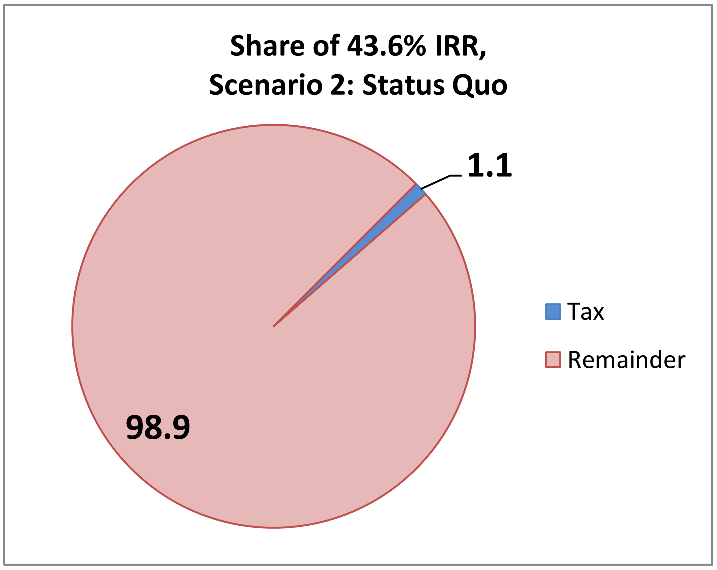
The IRR is projected to have a mean of 37.1% and a standard deviation of 17.6 percentage points after the simulation is run. This remains substantially higher than the WACC of 9.1%, indicating a profitable venture should the project move forward and the actual ore, price and cost figures remain within the assumed parameters.

Scenario Summary

The five tax regime scenarios examined here included a base case of no mining tax, the status quo of Manitoba's current mining tax regime, the previous 18% flat tax, and similar scenarios to the latter two but without the new mining tax holiday.

Examining the NPV results show that the higher tax rates and removal of the NMTH compared to the base case of no mining tax are effective in generating public revenue. The base case of no mining tax in scenario 1 has an IRR of 43.6%. Scenario 2's status quo tax regime lowers the IRR to 43.1%, a proportion of 1.1% of the 43.6% return by comparison, shown in Figure 21.

Figure 21: Share of 43.6% for Status Quo



Scenario 3 takes 1.6%, meaning the higher flat tax can expropriate a higher share of the rent without unduly affecting the overall return, though it is not much different from the Status Quo assuming a highly profitable mine. Removing the NMTH is a significant increase, with the shares of the tax taking about a quarter of the IRR, as shown in Figure 22 and Figure 23.

Figure 22: Share of 43.6% for Thresholds and No Tax Holiday

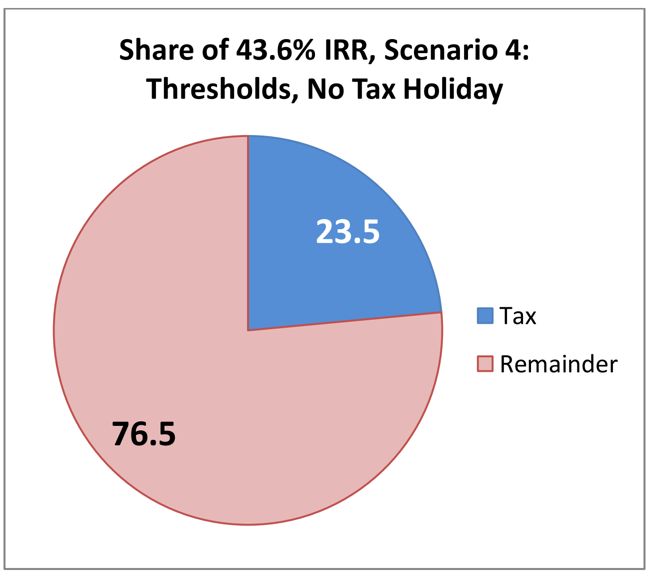
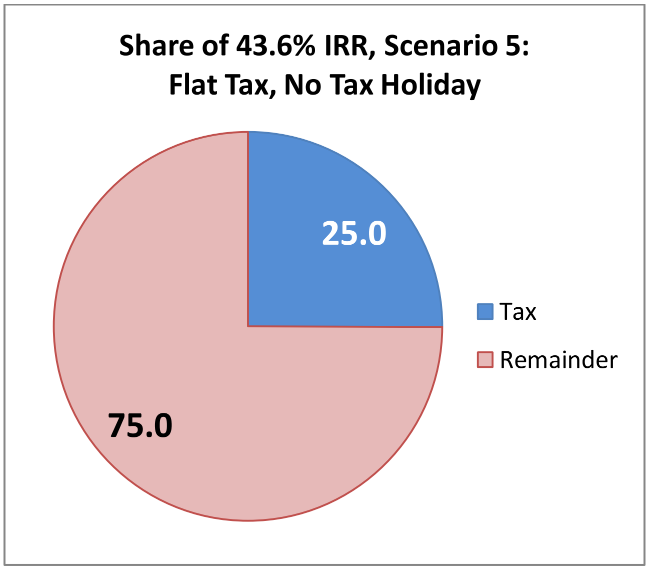


Figure 23: Share of 43.6% for Flat Tax and No Tax Holiday



The Monte Carlo simulation model showed that the mean IRR for all scenarios was higher than calculated without probability analysis. This indicates that returns could be greater than initially projected. If the taxing authority returned to a higher 18% flat tax from the current progressive structure, it would be feasible for a mining company as the change expropriates a small fraction of IRR. A more significant policy change would be to leave the rates unchanged and remove the NMTH. It would not leave the miner facing a significant risk of having zero profits or run losses. However, in both scenarios with the NMTH removed, there is a 3-4% chance of IRR being lower than 9.1% (the WACC). Capital could find better returns elsewhere. Table 13 summarizes the main findings.

Table 13: Scenario Summary of IRR

Scenario Summary
Internal Rates of Return

Scenario	**IRR (%)**	***Mean IRR (%)***	**Effective Mining Tax Rate (%)**	***Standard Deviation (percentage points)***
1) No Mining Tax	43.6	*48.7*	0.0	*21.7*
2) Status Quo	43.1	*47.5*	4.2	*20.5*
3) Flat Tax	42.9	*47.1*	5.5	*20.2*
4) Thresholds, No NMTH	33.4	*38.2*	16.8	*17.8*
5) Flat Tax, No NMTH	32.7	*37.1*	18.0	*17.6*

Each scenario returns an IRR that is profitable compared to the WACC. The effective mining tax rates show how much tax each scenario's regime takes in relation to profit. Scenarios 1 and 5 are straightforward applications of the rate, 0% with no mining tax and an 18% flat tax, respectively. The NMTH has a significant role in suppressing the effective rate. For Scenario 2, the highest mining tax rate is triggered at 17%, but the tax is not paid due to the NMTH until year 8. This leaves the effective tax rate at 4.2%. Scenario 3 is similar. Scenario 4 is the same as Scenario 2, but without the NMTH. In scenario 4, the 17% rate is reduced to 16.8% rate owing to the last year, with partial production, generating less than $100 million of profit and triggering a 15% tax rate.

Model Extensions

The model can be applied to other metals by changing the assumptions for grade and prices. For example, if a zinc ore body had higher grades, but lower prices, the model could generate projections with those inputs.

Model works reasonably well for real-life circumstances. For example, the Birchtree and Bucko Lake nickel mines have assumptions that can be incorporated into the model. The simulation's results are similar to the actual outcome. The Birchtree mine is characterized by a low grade. The Bucko Lake mine has low grades as well as high capital costs. The following results use 10,000 iterations.

- **Birchtree assumptions**: When a low grade such as 1.34% for Birchtree is used in the status quo scenario, the IRR after tax return is 24.4%, but has a 16% chance of an IRR lower than the WACC, indicating higher risk. Currently, the Birchtree mine is being considered for care and maintenance status.
- **Bucko Lake assumptions**: When $314.29/t for initial capital costs and $109.5/t for operating costs in year 1 are assumed, as well as a 1.43% ore grade, as published by CaNickel (2012), IRR after tax returns have a mean of 13.5% and a standard deviation of 14.9. This is not significantly different from the WACC of 9.1%. Mining tax is not levied as profits are too low to exceed New Mine Tax Holiday amounts. Before tax, there is a 6% chance of loss and the probability of negative returns increases to 16% after income taxes are applied. CaNickel's Bucko Lake mine is currently in care and maintenance status until nickel prices improve.

Model Limitations

The model is limited by issues including data availability, thorough taxation modelling, and fixed projections of certain variables. The extent of data available through financial and technical reports of mining companies is limited and estimating a cost function is limited to operating and capital costs per tonne. Since labour is not identified separately, another component of taxation, the Manitoba health and education levy (payroll tax) cannot be modelled. Different types of capital are not estimated for the sake of modelling federal corporate income tax. In addition, property taxes are not modelled. This leaves gaps in the model at all levels of government. Finally, the model fixes the terminal point of production at ten years. This makes ad valorem and specific royalties difficult to assess as they add to variable costs and raise the cut-off grade for metals. While mining companies can adjust production to account for a royalty, the model as it stands cannot.

Chapter 5: Conclusion

The Manitoba mining sector is important to the provincial economy. It is the most productive sector and pays among the highest wages. The presence of non-renewable resource revenue in any province is a precursor to debate about how to best extract public benefits. Manitoba's mining tax regime is set up as a resource rent tax with a progressive structure. The literature suggests resource rent taxation is the best tax for extracting resource rents without affecting the market-determined cut-off grade of extraction and the terminal point of a mine's life. However, measurement issues such as asymmetric information and other "quasi-rents" prevent any taxing authority from fully knowing how to distinguish resource rents.

A Monte Carlo simulation of a hypothetical Manitoba underground mine was created. The simulation provided a useful tool for evaluating the impact of mineral taxation policy projects. It certainly offered a better approach than conventional econometrics. Evaluating IRR versus the WACC showed that each tax regime scenario maintained a mining project's feasibility. The profit indicated by IRR left more than enough to cover the opportunity cost of capital. Returning to the higher, 18% flat tax would be manageable for a mining company with profits already above the 17% threshold. The model could be used to run scenarios with lower rates of profit. If the new mining tax holiday would be removed, a large portion of IRR would be expropriated. While the IRR would drop by about 25%, it would remain elevated compared to the cost of capital. However, an ultimately higher tax burden on a highly risky industry would increase risks further. Mining companies would be left with more risk to the IRR should the new mining tax holiday be eliminated completely.

While theoretically a government could tax a rent at 100% and the mine could remain competitively profitable, Manitoba taxes between 10% and 17% on profits, offsetting rent measurement and quasi-rent concerns. Manitoba's last major tax regime change was an 18% flat tax prior to 2009. While the tax cut did not lead to an increase in employment, it did correlate to increased capital investment. This correlation comes with caveats: the regression could not measure a dollar-for-dollar impact of the tax cut's value, the data points on the tax cut dummy were few, and the data on investment did not break out minerals from oil and gas extraction. This reveals the limits of econometrics in design an optimal mineral tax regime.

Several improvements in the simulation model could be made. Detail on costs could be greatly expanded. This would help with capital cost allowance calculations for income tax projections. On the revenue side, common financial forwards and futures could be incorporated to insulate the firm from substantial variation in prices, though it is not standard practice in the industry.

Concerning policy recommendations, moving back to the 18% flat tax would likely not impact an already profitable mining firm greatly. However, removing the new mining tax holiday would possibly be too onerous. If it were removed, it would likely require an accompanying lower rate. An alternate policy could be to shorten the holiday by reducing the eligible expenses. If there is substantial variability in prices, government could offer a program or subsidy for mining companies to partake in forwards and futures. This could be in the taxing authority's interest for reducing associated volatility in its own mining tax receipts.

There are several issues around any policy regarding the mining sector that this paper does not address. A good stock of non-renewable resources leads to questions of distributional fairness. Policy surrounding mining could be debated around such issues as which regions are entitled to benefits of the industry. Should the local governments benefit primarily or should the province or the federation be more prominent in getting financial benefits? Intergenerational fairness issues should be addressed, as production today reduces the stock of resources tomorrow. This leads to questions about the socially optimal rate of extraction, which may not necessarily be the same as the commercial optimum. The question of who benefits should also be open to scrutiny.

Appendix A: Price Index Calculations

A Fisher index was used for prices. This appendix illustrates the calculations.

The Fisher index uses geometric mean of Laspeyres and Paasche.

For the Laspeyres price index (RL):

$$R_L = \frac{\sum_i (P_{it} * Q_{it})}{\sum_i (P_{i\,2002} * Q_{i,t})}$$

For the Paasche price index (RP):

$$R_P = \frac{\sum_i (P_{it} * Q_{it})}{\sum_i (P_{i\,2010} * Q_{i,t})}$$

For the Fisher price index (RF):

$$R_F = \sqrt{R_L * R_P}$$

Appendix B: Simulation Model Equations

Production Function

$$Q = O * g$$

Q ≡ Nickel concentrate (tonnes)
O ≡ Ore production (000 tonnes)
g ≡ Metal grade (%)

Revenue Function

$$R = P * Q$$

R ≡ Total revenue ($000)
P ≡ Price ($/kg)

Cost Function

$$C = VC * O + K_i + K_s$$

C ≡ Total cost ($000)
VC ≡ Operating cost per tonne ($)
K_i ≡ Initial capital costs ($000)
K_s ≡ Sustaining capital costs ($000)

Profit Functions

$$\Pi_b = R - C$$
$$\Pi_a = R - C - T = \Pi_b - T$$

Π_b ≡ Profit before tax
Π_a ≡ Profit after tax
T ≡ Total tax ($000)

Tax Function

$$T = CIT_{Fed} + CIT_{MB} + M_i$$
$$CIT_{Fed} = \Pi_b * 15\%$$
$$CIT_{MB} = \Pi_b * 12\%$$

CIT_{Fed} ≡ Federal CIT ($000)
CIT_{MB} ≡ Manitoba CIT ($000)
M_i ≡ Mining tax ($000), ($i=1,2,\ldots,n$)
n ≡ Number of mining tax scenarios

Net Present Value

$$NPV = \sum_{t=0}^{9} \left(\frac{\Pi_{\mathrm{jt}}}{(1+r)^{(t-1)}} \right); j = (b, a)\,; t = (1,2, \dots ,10)$$

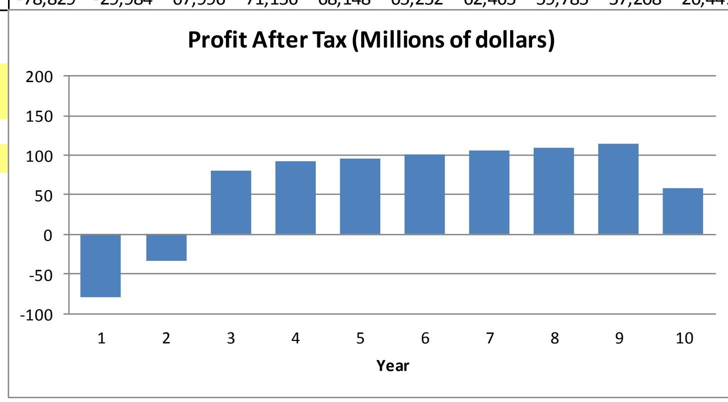
NPV ≡ Discounted cash flow sum, cumulative value of NPV profit/loss ($000)
r ≡ discount rate (5.72%)

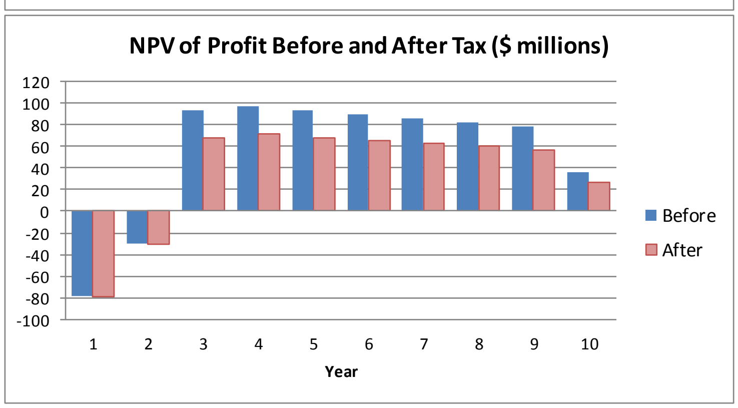
Appendix C: Simulation Model Results

Scenario 1: No Mining Tax

Tax Function	Units/Notes	Year 1	2	3	4	5	6	7	8	9	10	Cumulative
NO MINING TAX												
Federal CIT Rate	15%											
Federal CIT Revenue	$000	0	0	16,634	18,994	19,849	20,737	21,661	22,621	23,619	11,914	156,029
Manitoba CIT Rate	12%											
Manitoba CIT Revenue	$000	0	0	13,308	15,195	15,879	16,590	17,329	18,097	18,895	9,531	124,823
Subtotal: Income Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Mining Tax												
Mining tax rate	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Tax ex-ante Deductions	$000											0
Calculations of Deductions												
Cumulative Mining Tax Revenue	$000											
New Mine Tax Holiday Pool	$000											
Mining Tax ex-post NMTH	$000											0
Total Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Profit Function, ex-post tax												
After Tax	$000	-78,829	-32,716	80,954	92,437	96,598	100,922	105,417	110,089	114,944	57,981	647,797
Net Present Value (NPV)												
WAVG Capital Cost (%)	9.11											
NPV Before Tax	$000	-78,829	-29,984	93,145	97,474	93,353	89,386	85,569	81,898	78,368	36,229	546,609
NPV After Tax	$000	-78,829	-29,984	67,996	71,156	68,148	65,252	62,465	59,785	57,208	26,447	369,645

Internal Rate of Return	
Before Tax (%)	57.9
After Tax (%)	43.6
Effective Mining Tax	0.0

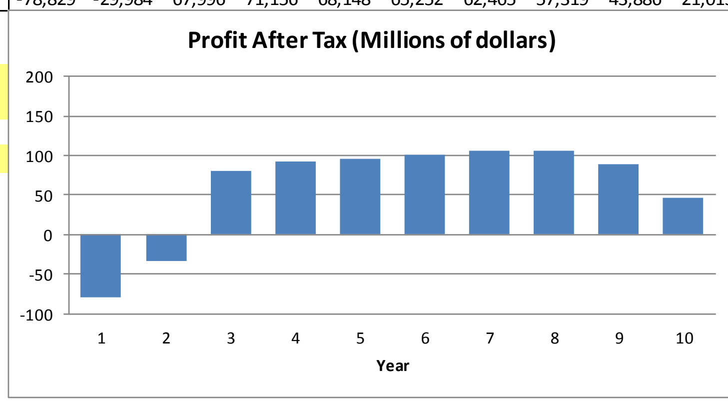


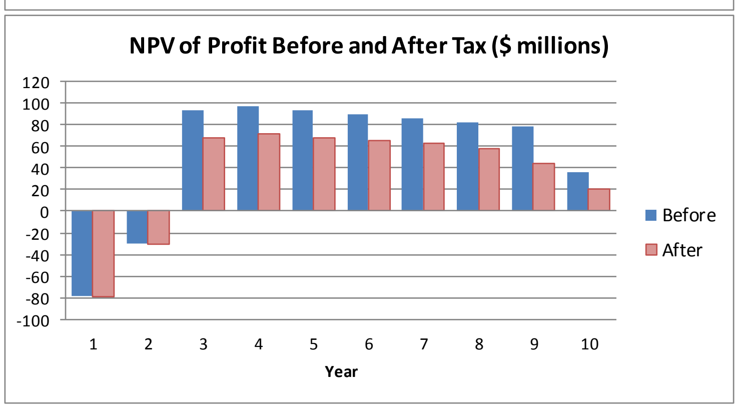


Scenario 2: Status Quo

Tax Function	Units/Notes	1	2	3	4	5	6	7	8	9	10	Cumulative
		Year										
STATUS QUO												
Federal CIT Rate	15%											
Federal CIT Revenue	$000	0	0	16,634	18,994	19,849	20,737	21,661	22,621	23,619	11,914	156,029
Manitoba CIT Rate	12%											
Manitoba CIT Revenue	$000	0	0	13,308	15,195	15,879	16,590	17,329	18,097	18,895	9,531	124,823
Subtotal: Income Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Mining Tax												
Mining tax rate	%	0.0	0.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	15.0	
Tax ex-ante Deductions	$000 (10/15/17%)	0	0	18,852	21,526	22,495	23,502	24,549	25,637	26,768	11,914	175,245
Calculations of Deductions												
Cumulative Mining Tax Revenue	$000	0	0	18,852	40,379	62,874	86,377	110,926	136,563	163,331	175,245	
New Mine Tax Holiday Pool	$000	157,658	157,658	138,806	117,280	94,784	71,282	46,733	21,095	0	0	
Mining Tax ex-post NMTH	$000	0	0	0	0	0	0	0	4,542	26,768	11,914	43,224
Total Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	45,260	69,282	33,359	324,076
Profit Function, ex-post tax												
After Tax	$000	-78,829	-32,716	80,954	92,437	96,598	100,922	105,417	105,547	88,177	46,067	604,574
Net Present Value (NPV)												
WAVG Capital Cost (%)	9.11											
NPV Before Tax	$000	-78,829	-29,984	93,145	97,474	93,353	89,386	85,569	81,898	78,368	36,229	546,609
NPV After Tax	$000	-78,829	-29,984	67,996	71,156	68,148	65,252	62,465	57,319	43,886	21,013	348,422

Internal Rate of Return	
Before Tax (%)	57.9
After Tax (%)	43.1
Effective Mining Tax	4.2

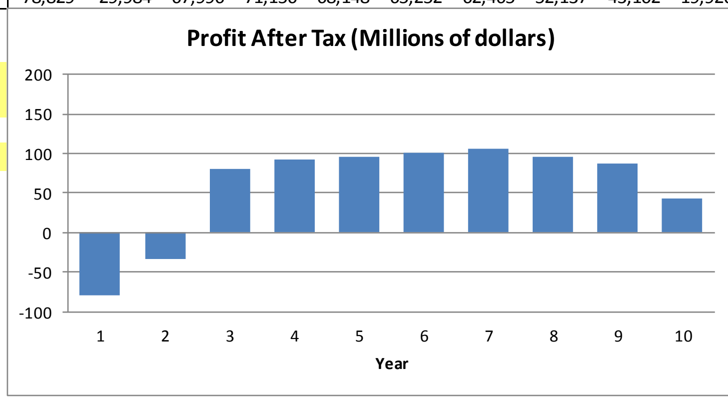


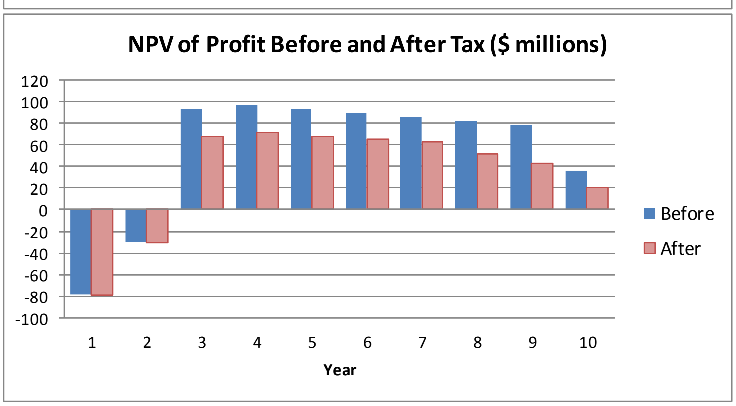


Scenario 3: Flat Tax at 18%

Tax Function	Units/Notes	1	2	3	4	5	6	7	8	9	10	Cumulative
FLAT TAX												
Federal CIT Rate	15%											
Federal CIT Revenue	$000	0	0	16,634	18,994	19,849	20,737	21,661	22,621	23,619	11,914	156,029
Manitoba CIT Rate	12%											
Manitoba CIT Revenue	$000	0	0	13,308	15,195	15,879	16,590	17,329	18,097	18,895	9,531	124,823
Subtotal: Income Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Mining Tax												
Mining tax rate	%	0.0	0.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	
Tax ex-ante Deductions	$000 (18%)	0	0	19,961	22,793	23,819	24,885	25,993	27,145	28,342	14,297	187,235
Calculations of Deductions												
Cumulative Mining Tax Revenue	$000	0	0	19,961	42,754	66,573	91,458	117,451	144,596	172,939	187,235	
New Mine Tax Holiday Pool	$000	157,658	157,658	137,697	114,904	91,086	66,201	40,208	13,062	0	0	
Mining Tax ex-post NMTH	$000	0	0	0	0	0	0	0	14,083	28,342	14,297	56,722
Total Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	54,801	70,856	35,742	337,575
Profit Function, ex-post tax												
After Tax	$000	-78,829	-32,716	80,954	92,437	96,598	100,922	105,417	96,006	86,602	43,684	591,075
Net Present Value (NPV)												
WAVG Capital Cost (%)	9.11											
NPV Before Tax	$000	-78,829	-29,984	93,145	97,474	93,353	89,386	85,569	81,898	78,368	36,229	546,609
NPV After Tax	$000	-78,829	-29,984	67,996	71,156	68,148	65,252	62,465	52,137	43,102	19,926	341,369

Internal Rate of Return	
Before Tax (%)	57.9
After Tax (%)	42.9
Effective Mining Tax	5.5

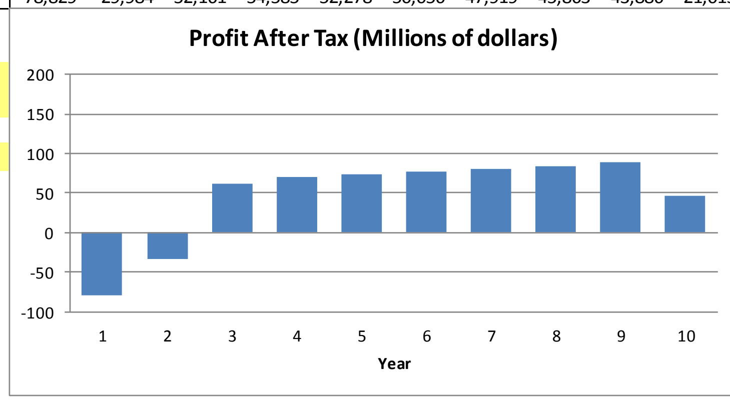


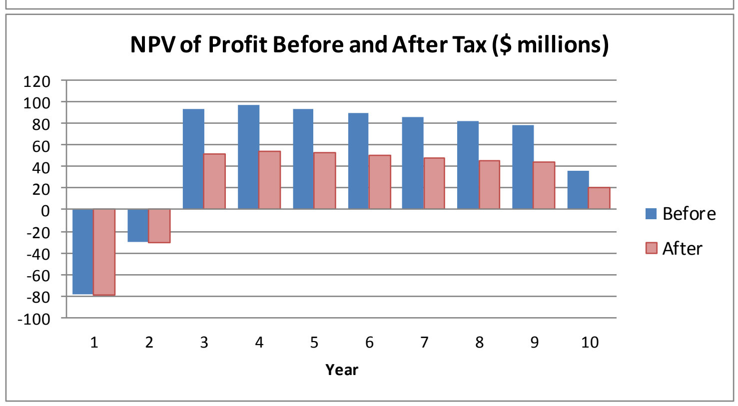


Scenario 4: Thresholds with No New Mining Tax Holiday

Tax Function	Units/Notes	Year 1	2	3	4	5	6	7	8	9	10	Cumulative
THRESHOLDS, NO NEW MINING TAX HOLIDAY												
Federal CIT Rate	15%											
Federal CIT Revenue	$000	0	0	16,634	18,994	19,849	20,737	21,661	22,621	23,619	11,914	156,029
Manitoba CIT Rate	12%											
Manitoba CIT Revenue	$000	0	0	13,308	15,195	15,879	16,590	17,329	18,097	18,895	9,531	124,823
Subtotal: Income Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Mining Tax												
Mining tax rate	%	0.0	0.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	15.0	
Tax ex-ante Deductions	$000 (10/15/17%)	0	0	18,852	21,526	22,495	23,502	24,549	25,637	26,768	11,914	175,245
Calculations of Deductions												
Cumulative Mining Tax Revenue	$000	0	0	18,852	40,379	62,874	86,377	110,926	136,563	163,331	175,245	
New Mine Tax Holiday Pool	$000											
Mining Tax ex-post NMTH	$000	0	0	18,852	21,526	22,495	23,502	24,549	25,637	26,768	11,914	175,245
Total Tax	$000	0	0	48,794	55,716	58,223	60,830	63,539	66,355	69,282	33,359	456,098
Profit Function, ex-post tax												
After Tax	$000	-78,829	-32,716	62,102	70,911	74,102	77,420	80,868	84,452	88,177	46,067	472,553
Net Present Value (NPV)												
WAVG Capital Cost (%)	9.11											
NPV Before Tax	$000	-78,829	-29,984	93,145	97,474	93,353	89,386	85,569	81,898	78,368	36,229	546,609
NPV After Tax	$000	-78,829	-29,984	52,161	54,585	52,278	50,056	47,919	45,863	43,886	21,013	258,948

Internal Rate of Return	
Before Tax (%)	57.9
After Tax (%)	33.4
Effective Mining Tax	16.8

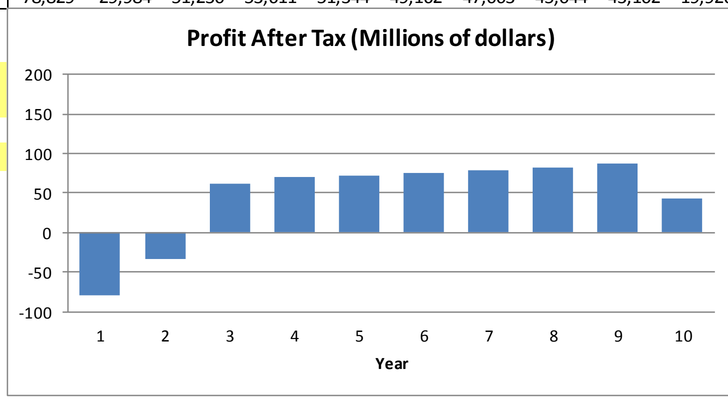


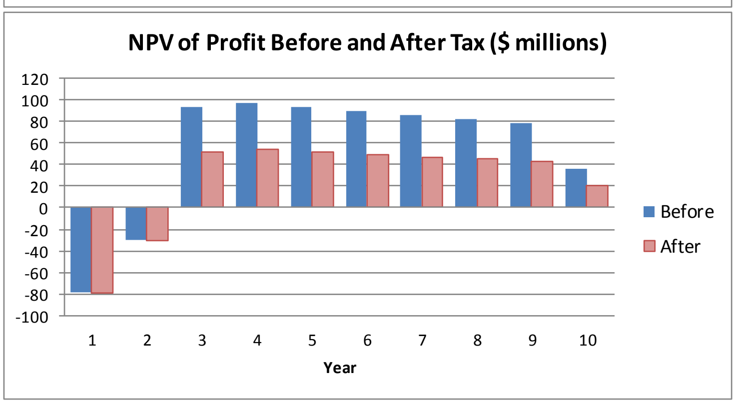


Scenario 5: Flat Tax with No New Mining Tax Holiday

Tax Function	Units/Notes	1	2	3	4	5	6	7	8	9	10	Cumulative
		Year										
FLAT TAX, NO NEW MINING TAX HOLIDAY												
Federal CIT Rate	15%											
Federal CIT Revenue	$000	0	0	16,634	18,994	19,849	20,737	21,661	22,621	23,619	11,914	156,029
Manitoba CIT Rate	12%											
Manitoba CIT Revenue	$000	0	0	13,308	15,195	15,879	16,590	17,329	18,097	18,895	9,531	124,823
Subtotal: Income Tax	$000	0	0	29,942	34,189	35,728	37,327	38,990	40,718	42,514	21,445	280,853
Mining Tax												
Mining tax rate	%	0.0	0.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	
Tax ex-ante Deductions	$000 (18%)	0	0	19,961	22,793	23,819	24,885	25,993	27,145	28,342	14,297	187,235
Calculations of Deductions												
Cumulative Mining Tax Revenue	$000	0	0	19,961	42,754	66,573	91,458	117,451	144,596	172,939	187,235	
New Mine Tax Holiday Pool	$000											
Mining Tax ex-post NMTH	$000	0	0	19,961	22,793	23,819	24,885	25,993	27,145	28,342	14,297	187,235
Total Tax	$000	0	0	49,903	56,982	59,546	62,212	64,983	67,863	70,856	35,742	468,088
Profit Function, ex-post tax												
After Tax	$000	-78,829	-32,716	60,993	69,644	72,779	76,037	79,424	82,944	86,602	43,684	460,562
Net Present Value (NPV)												
WAVG Capital Cost (%)	9.11											
NPV Before Tax	$000	-78,829	-29,984	93,145	97,474	93,353	89,386	85,569	81,898	78,368	36,229	546,609
NPV After Tax	$000	-78,829	-29,984	51,230	53,611	51,344	49,162	47,063	45,044	43,102	19,926	251,669

Internal Rate of Return	
Before Tax (%)	57.9
After Tax (%)	32.7
Effective Mining Tax	18.0





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