“TO CUT, OR NOT TO CUT”
AVOIDING THE NATURAL RESOURCE CURSE THROUGH OPTIMAL FORESTRY MANAGEMENT

by

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Abstract

The natural resource curse is a controversial theory in which some countries, rich in natural resource endowments, economically progress at a slower pace than countries that have fewer amounts of natural resources. This paper uses Canadian forestry data to empirically test Phillip A. Neher's theoretical model of a sustainable forestry industry. The conclusion drawn argues that although the Canadian forestry industry has successfully avoided any symptoms of a resource curse, it has done so by using policy regulations that are designed around the conservation of its forests alone, with no regard to the sustainability of the forestry industry itself.

Introduction

Claims of a natural resource curse are based on the observation that countries rich with natural resources have grown slower than countries that have fewer resources. There have been a number of studies throughout the late 20th century that have investigated this correlation using evidence accumulated from the poor growth experiences of resource rich countries. Concerns about a natural resource curse first emerged during the inter-war period after many Latin American economies began to suffer from a global decline in commodity prices. Initial scepticism regarding natural resource led development was based primarily on forecasts of declining global demand and commodity prices.[1] Studies supporting the “curse”, argue that it is a verifiable empirical fact, even after you control for these trends in commodity prices. These studies argue that because so many poorer countries still have an abundant amount of natural resources, it is important to better understand the roots of the failure in natural resource led development.[2]

On the other hand, there are studies that question the existence of the natural resource curse, stating that there are other variables, more correlated with economic growth, that explain why these resource rich countries experience slower growth. Using the Canadian forestry sector as a case study and Phillip A. Neher's theoretical model pertaining to optimal resource extraction, this paper will examine the effects of certain economic policies and institutional structures that

[1] Sachs et. al. (2001) pg 828
[2] Ibid, pg 829

influence a country's tendency to be affected by the resource curse. I will argue that although Neher's model may be theoretically sound, its practical application in the Canadian context is somewhat feeble. Explanations will be provided for the model's failings in the Canadian case study. These explanations and the model's failings also contribute to our understanding of how the Canadian resource sector has successfully avoided the natural resource curse during the twentieth century.

The Natural Resource Curse

There are a large number of theories that attempt to explain the negative relationship between natural resources and growth. One of the earliest explanations was that easy riches lead to sloth,[3] where societies endowed with plentiful resources misused their resource advantage. More recent thinking in development economics attributes the cause of the resource curse towards the lack of positive externalities from the natural resource sector compared to the manufacturing sector of a country's economy. These theories are based mostly around such development literature of the 1950's and 1960's as well as the Dutch Disease Models of the 1970's and 1980's, with a large majority involving certain technology spillovers that affect a countries optimal growth path.

Hirschman (1958) asserted that beneficial "forward and backward linkages" from a country's primary exports to the rest of its economy would be quite small. In other words, it is manufacturing, as opposed to natural resource

[3] Bodin (1962) pg 4

production, which leads to a more complex division of labour and therefore to a higher standard of living. This pessimistic view of resource led growth resulted in an onslaught of literature describing the successful cases of “staples-led growth”. A case study conducted by Roemer (1970) on Peru’s resource-led growth challenged this claim, stating that Peru was able to grow effectively regardless of its large resource sector. This argument, in favour of staples-led growth, successfully argued that a country with specific characteristics, although difficult to determine for each country, could in fact escape the resource curse.

Dutch Disease models illustrate how the presence of large resource sectors, or booms in natural resources, affect the distribution of employment throughout the economy. The theory states that an increase in revenues from the natural resource sector will reduce the industrialization of a nation’s economy by raising the exchange rate, in turn making the manufacturing sector less competitive both domestically and internationally.[4] However, it is hard to determine if the Dutch disease effect is the actual cause of this reduction in competitiveness because there are many other factors at play in the global economy that may contribute to this decrease. Although the theory usually refers to a natural resource discovery or boom, it can also refer to any development that results in a large inflow of foreign currency, a sharp surge in natural resource prices, foreign assistance or foreign investment into the resource sector.[5] As there are many potential factors that could generate Dutch Disease effects, it

[4] Sachs et. al. (1997) pg, 5
[5] Ebrahim-zadeh (2003) pg. 24

becomes quite difficult to determine whether these effects are in fact resource driven.

Matsuyama (1992) uses a two-sector, agriculture and manufacturing model to explore the effects of the Dutch Disease. Manufacturing evolves through learning-by-doing, which is external to individual firms. In other words, the rate of human capital accumulation is proportional to total sector production and not the production of the individual firm. As a result, the social return to manufacturing employment exceeds the private return. Therefore, any force that shifts the economy away from manufacturing and towards the agricultural sector will effectively lower the growth rate of the economy by reducing the learning-induced growth of manufacturing. Matsuyama demonstrates that free trade in land-intensive economies could actually slow economic growth by enticing the economy to shift its resources away from manufacturing and towards agriculture, as there are more potential profits to be made. Other explanations of the natural resource curse also tend to go along the lines of this crowding out effect. Gylfasion et. al. (1999) and Gylfason (2000) suggest that natural resource abundance could crowd out entrepreneurial activity or innovation if the wages in the natural resource sector were high enough to encourage any potential innovators or entrepreneurs to work in the resource sector instead of the manufacturing sector.[6]

[6] Ibid

Another line of thinking asserts that resources are in fact not the problem. Instead it is the volatility of their prices that harms growth. This volatility translates into greater uncertainty for primary commodity producers, which also extends through other sectors in resource rich countries. Furthermore, greater uncertainty can reduce capital accumulation as a result of the greater risk or because it raises the option value of waiting. This creates an undesirable scenario for potential financiers, causing them to be hesitant when determining whether or not to invest in any sector of the economy affected by this ambiguity.

Mehlum et. al (2005) claims that the difference in the economic growth of resource rich countries can be found in the varying quality and efficiency of the country's institutions. It is a measurable fact that resource rich countries show huge variations in their institutional quality. Where those that do well in terms of economic growth also have sound institutions and political structures, while those that perform poorly do not. It is intuitive to think that the potential economic benefits from a new resource discovery should be quite different in a war stricken country such as Afghanistan compared to a more staple nation like Canada. Mehlum et. al. focuses on the pressures between production and special forms of rent-seeking. Although any form of rent seeking is harmful to an economy's development, they differ in the severity of harm. Mehlum et. al. divides an economy's institutions into two categories: "Producer Friendly" and "Grabber Friendly". When institutions are bad, or grabber friendly, rent seeking is made possible outside the productive economy, for example, when there are dysfunctional democracies or low government transparency that entice corruption. These Grabber Friendly institutions create disadvantages for producers when competing for natural resource rents, making production and rent-seeking competing activities. Better institutions, or “Producer Friendly” institutions have a difficult time rent seeking unless they are also a producer of goods in the market they are attempting to rent seek in. In competition for natural resource rents, a large producer has an edge when it comes to lobbying for subsidies, public support, etc. Therefore, production and rent seeking are complementary activities when institutions are producer friendly. Grabber friendly institutions divert scarce entrepreneurial resources out of production and move them into unproductive activities where there are gains from specializing. Mehlum et. al hypothesizes that an economy with grabber friendly institutions seems to result in natural resources pushing aggregate income levels down, while an economy with producer friendly institutions, natural resources push incomes up. They conclude that the resource curse is only present in countries with these “grabber friendly” institutions.

Countries with different institutions, manage their resources differently, which is what leads to the large variation in the growth paths of resource abundant countries. Assuming that institutions are endogenous to resource incomes, further strengthens this divergent pattern, as they would be further hampered by a decrease in aggregate income levels.

In order to escape the natural resource curse, countries need sound institutions that have the ability to efficiently exploit a country's resource endowments and constrain rent grabbing through economically efficient and sustainable Neher-type regulatory practices. Canada's forestry sector is a prime example of one of those countries. With its extensive timber industry it has been able to successfully avoid any resource curse effects that could have hampered or destroyed one of the largest manufacturing sectors in its economy. For these reasons, Canada makes for a good case study in which to empirically test Neher's optimal resource management model. The following section will provide a brief historical background of Canada's forestry industry. It will describe the successes and failures of establishing a proper forestry conservation program while still allowing for an economically viable timber manufacturing industry.

Canadian Forestry Conservation[7]

Approximately 10 percent of the world's forests lie within Canadian borders. The forests that are used today began developing approximately 10,000 years ago, around the end of the last ice age. Even after being exploited for many centuries, Canadian forests are still virtually intact. Since European colonization, only six percent of Canada's forestland has been developed into other uses. The main loss of forestland during the colonial period came as a result of the Canadian fur trade. The fur trade was the leading economic activity for 200 years in North America and provided the incentive and financial support for European

[7] Historical facts regarding Canadian forestry taken from Drushka (2003)

exploration and colonization, which in turn damaged valuable forestland. The industrialization period created even greater demands on Canadian forests. Construction of railways and bridges, together with increased settlement and a considerable serge in technological advancement, which improved the efficiency of timber harvesting, all played a large roll in severely altering the landscape of Canada's forests. In 1900, the condition of Canadian forestland was in its worst state since the period of glaciation and it was at this point in Canadian history were the notion of forest conservation began to gain momentum. The North American conservation movement was based around ideas and concepts that began to appear long before the end of the nineteenth century, about the time when forestation in Canada had become widespread. One of the key components of North American conservation was that the planning and management of forests as well as other natural resources should be the responsibility of scientifically trained professionals as apposed to the policy in place at the time, which gave the responsibility to politically appointed officials. This required a reformulation of the partnership between government and industry to allow for the inclusion of such scientific professionals. The primary function of these scientists was to ensure that the utilization of the forests was done in a manner that would allow for its future well-being. During this time it became the understanding of a large majority of political and conservationist leaders that forest use and forest conservation would have to go hand in hand in order for the forests of Canada to survive in the long run. It would take many decades for policy makers and foresters to configure the implications of maintaining stable Canadian forests while at the same time making full economic use of them. The theory used to describe the process of these established limits of use was known as sustained yield. This principle has since been the main focus of forest-policy.

The Great War hampered the forestry conservation movement, however upon its conclusion, timber-based forest industries resumed their expansionary growth, now with an even faster rate of technological advancements. The eastern and central saw mill industries were replaced with a dynamic pulp and paper sector, which was able to utilize smaller trees as well as use tree species not suitable for lumber. This ability to use smaller trees than the lumber industry provided support for conservation, however at the same time also enabled the industry to harvest much more intensively and extensively. Moreover, the pulp and paper sector required large investments that forced the industry to think much more towards its long run stability, further improving conservation efforts. Post war technological advancements also improved the efficiency of forestry machinery in both the lumber and pulp and paper industries, allowing a more efficient harvesting of timber. Steam powered machines were replaced with smaller, less expensive equipment powered with more efficient, internal combustion engines. This allowed smaller firms and individuals to purchase these new machines, creating a more diverse logging sector, which was able to reach smaller stands of timber, previously inaccessible to the large machinery loggers. This increase in efficiency was sparked by the technological advancements during the Great War and allowed for a huge boom in the forestry industry, peaking in 1929. This boom overshadowed the conservationist idea of maintaining social and economic stability through the restrained efficient use of natural resources.

The Great Depression saw lumber production fall by 60 percent with many sectors of forestry going bankrupt. As a result, provincial governments were reluctant to enforce the few forest-management regulations then in existence. It was only at this point, when conservation efforts seemed to have bottomed out, that people began to think seriously about placing effective regulations on the forestry industry in order to maintain their cherished natural resource far into the future. The onset of World War II forced the entire forest sector to mobilize in order to support the Allied effort. One of the main lessons that came out of the war was that Canada's forestry industry was not only an integral part of economic and environmental improvement but was also of great strategic importance. The most crucial material contributed by Canada to the war effort was timber harvested from its forests. As the realized importance of Canadian forests grew, so too did the country's efforts to protect the long run sustainability of the resource. Beginning in 1943 a number of provincial royal commissions were established, addressing "the establishment of forest yield on a continuous production basis in perpetuity."[8] Throughout the next decade the fragility of Canadian forests became more understood through numerous studies and reports conducted throughout the country. This resulted in more stringent

[8] Drushka (2003), pg. 57

regulations being placed on the forestry industry in order to protect its future prosperity. The conservation policies adopted throughout the post-war period were characterized with both strengths and weaknesses. From an industry perspective, these sustained yield policies were in fact a great advantage. For the most part, the adoption of these policies did not require harvesting slowdowns or mill closures. Instead, they allowed for a degree of certainty and security regarding the future availability of timber. In fact, these policies, more often then not allowed for future increases in harvesting levels that encouraged increased investment flow into the industry. However there were some shortcomings to Canadian forest conservation policies. Canada's timber industry has always been a net exporter. As a result, the sustained yield policies intended to produce an even flow of timber each year hampered the industry's potential profitability because of fluctuating demand in export markets. These sustained yield policies force a fixed amount of timer to be produced which often caused the industry to produce too much in times of decreased market demand and restricted the volume of timber produced in times of increased market demand. This inefficient production of timber increased the severity of price fluctuations and caused economic instability within Canada. Furthermore, these policies limited the type of tree species harvested for timber. This resulted in large areas of forest not being cut at the appropriate time which led to sections of abnormally old and over-mature forests susceptible to insects and disease.

Regardless of the problems, the conservation policies adopted by Canada during the post World War II era did in fact accomplish their main objective. They brought an end to the unrestrained harvesting of the country's forests. Through these policies, the maintenance of the country's permanent forests became a country wide accepted priority. Although the harvest levels determined under these policies may not have been the correct ones, the important achievement made was the adoption of a theory and methodology to maintain forests throughout time. Canada's initial policies and regulations were inflexible to price and demand changes, such as changes in the interest rate. This was because Canada's main objective was to constrain rent grabbing through ensuring sustained yield harvest techniques, not through the establishment of a policy that maximized profits while sustaining Canada's forests. A simplified version of the theory and regulatory methodology is represented by Philip A. Neher's models of biological sustainability and economic efficiency. Neher focuses on the creation of a sustainable forest while still allowing for the economically efficient exploitation of its resources.

Now or Later: Optimal Resource Extraction Theory

One of the main causes of the natural resource curse arises from the presence of institutional structures and policies that are unable to restrain the inefficient exploitation of renewable resources. The major sources of overexploitation include unspecified property rights, rent seeking policies, poverty and simply a lack of information or understanding about the stocks and flows of resources.

During the 20th century policies were designed on the basis of scientific management and the pursuit of sustained yields. In order to understand the objectives of a policy pertaining to efficient harvesting of a renewable resource such as timber our focus will be on a simple optimal harvesting strategy for forests put forth by Philip A. Neher (1990). In his model, Neher provides three forestry management policy solutions that are viable under three distinctly different scenarios.

Maximum Sustained Yield:

The central question in forestry economics is the question of "when to cut?" In other words should timber harvesting take place now or later? This question is answered by using detailed data relating to a forest's maturation period as well as comparing the market price received for timber against investing in other assets. Each tree is a distinct entity, which makes it possible to monitor each timber stand individually. As a result, foresters are able to track each tree's maturation process over time in exact ways that cannot be applied to other renewable resources such as fish. A tree's life cycle is usually expressed in real value terms. In Neher's model, P(t) is used to represent the real value of a tree at time t. This value is computed net of harvesting and replanting costs. Figure 1 illustrates this function graphically. This net commercial value is usually called the "stumpage". It begins as a negative value during the first few years of a trees life and then rises from zero as the tree gets older, but at a decreasing rate, until disease and rot cause the tree's value to actually decrease. Therefore, the value of the tree depends explicitly on its age. In order to allow for the regeneration of a

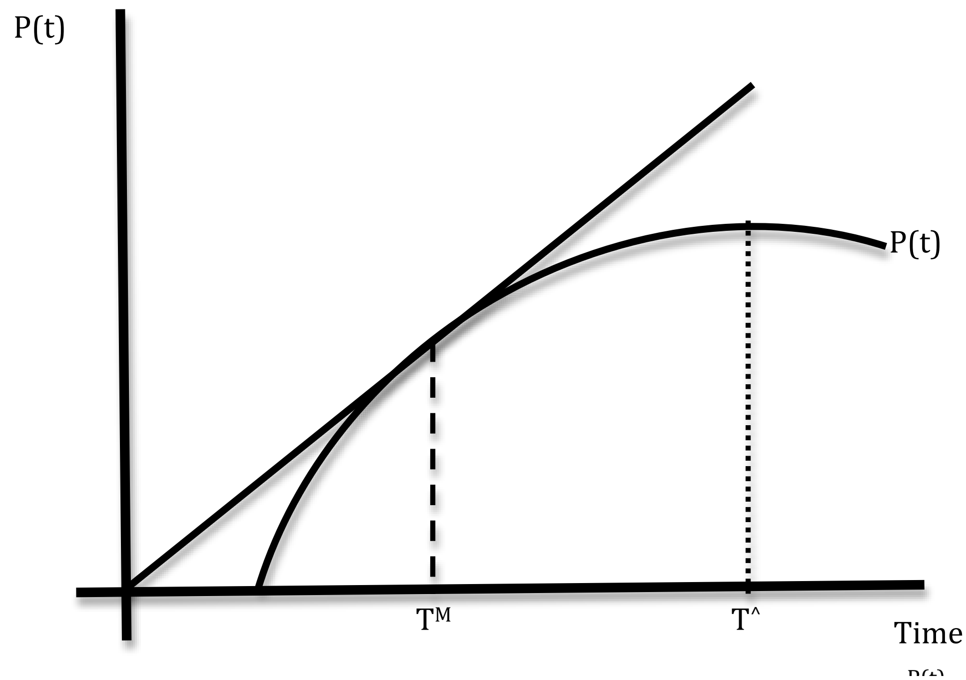

Figure 1: The net (of harvesting and other costs) value of a commercial tree as it ages

forest, a “rotation period” needs to be established. In order to maintain the yield of a forest, the annual harvest of trees needs to equal the amount of trees planted one year earlier. Therefore, it is the objective of a forester to select a rotation period to maximize the sustained yield of the forest. This is the maximum sustained yield (MSY) objective as described by Neher. An example of a sustainable rotation period would be, if there are forty trees, and the rotation period is determined to be forty years, then one tree would be cut each year. If the rotation period were in fact twenty years, then two trees would be cut each year. Neher generalizes this method as follows. If there are n trees worth P(t) and t=T represents the rotation period, then n/T would be cut each period having the value nP(t)/T. If we normalize n to a constant number of trees, the objective then becomes to choose T in order to:

$$\text{Max } nP(t)/T. \qquad [1]$$

Differentiating [1] will yield

$$dP(T)/dT = [TP'(T) – P(T)]/T^2 \qquad [2]$$

Rearranging,

$$P'(T^M)/P(T^M) = 1/T^M \qquad [3]$$

The MSY rotation period is T^M. At this point the marginal yield (P'(t)) equals the average yield (P(t)/t). Figure 1 illustrates the MSY solution where $t = T^M$. The solution is characterized by the point on the P(t) line where a ray drawn from the origin is tangent to the P(t) line. It is noteworthy to mention that $P(T^M)$ is less than the maximum value an individual tree could yield, P(T^). However, Neher argues that it is in fact more profitable in the long run to “cut out the old wood” in order to allow for new, faster-growing trees to occupy the space.

A Single Harvest:

Although the MSY solution derived above is ideally the first best solution, it neglects to include any sort of interest rate on alternative assets. In order for the MSY model to be economically efficient, trees have to be viewed as assets that can be cut and sold with the proceeds invested at some positive interest rate (r). The inclusion of a market interest rate will affect the rotation period of trees. For example, if r was very high, say 100 percent per year, compared with a 2 percent per year rate of return from harvesting a tree, then trees would appear to be a poor investment compared with other assets. In this example a tree with the stumpage value of $100.00 would grow to be worth $200.00 if it were cut and sold today and its earnings invested for one year. If instead that same tree were left to grow in the ground for another year, its value would only increase to $102.00. In this case, the rotation period should be shortened to exploit the high interest rate. Shortening the rotation period would bring the two rates of return closer together. Foresters still face the same general problem of maximizing the value of their trees by choosing the appropriate time to harvest. However the added market interest rate on assets forces them to focus on the discounted present value of their trees in order to determine what their future harvest will be worth. We can focus the problem to one harvesting period by assuming a finite time horizon. The forester is only concerned with harvesting his trees once and will not replace his existing trees with another crop after the existing stand is cut. In other words the land has no opportunity cost associated with it, including its use in supporting a subsequent growth of trees. To formulate this problem, let q(t) equal the value of the tree (net of harvesting costs) at some point in time (t). Then, q(0) is the new present value of the tree when it begins to grow and q(T) is its value at harvest time when the tree is T years old. If we assume for simplicity that interest is paid and compounded continuously we arrive at:

$$q(0) = e^{-rt}q(T) \qquad [4]$$

Using this continuous formulation, foresters would want to maximize q(0) by choosing T. However they are constrained by the market price for their timber, which imposes a price of only P(T) for each tree when harvested. As a result, the problem is to choose T in order to:

$$\text{Max } q(0) = e^{-rt}q(T) \qquad [5]$$

$$\text{S.T. } q(T) = P(T)$$

Figure 2 illustrates the solution to this problem. The P(t) line still represents the market value of each tree as it first rises and then falls with age. This represents the right side of the constraint. On the other hand, the present value of the trees grows exponentially at the rate r as time passes and the harvest is postponed.

$$q(T) = q(0)e^{rt} \qquad [6]$$

This equation represents an infinite number of exponentially increasing current values of each tree. Each one corresponds to a different present value of each tree (q(0)). Figure 2 illustrates three of these possibilities. The goal of the forester is to choose T so that the largest possible present value (q(0)) is obtained. As illustrated, if the trees are processed before (T*(-)) or after (T*(+)) the optimal age (T*), the corresponding q(0) will be less than it could be at q(0)*. Values larger

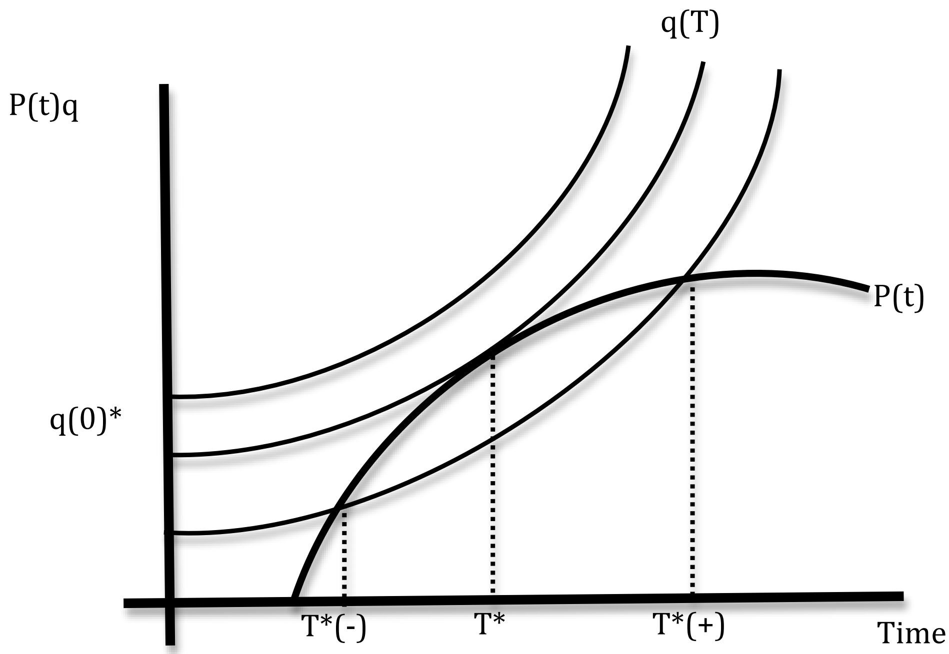

Figure 2: The most profitable time to cut a tree when a single harvest is contemplated

than q(0)* are not obtainable due to the market price constraint imposed on the foresters timber (P(T)). The solution to the problem lies with T* maximizing q(0) at q(0)*, which does not violate the constraint imposed by the market price for timber P(T). This solution is illustrated in figure 2 where the q(t) line is tangent to the P(t) line. This solution states that trees should be harvest when their natural rate of return equals the market interest rate.[9] As Philip Neher states "they should be cut when their value grows as fast 'on the stump' as 'in the bank'".[10] This graphical solution can also be obtained more algebraically as well. Looking at [2] it can be seen that the present value of a tree increases as P(T) rises through time. It is this price effect that motivates a forester's incentive to

[9] Fisher (1930)
[10] Neher (1990) pg. 66

postpone the harvest. On the other hand, the forester also discounts the future worth of any asset which in turn reduces the present value of harvested trees as the harvesting date is extended. This discounting effect motivates the forester's incentive to harvest early. The optimal harvest time (T*) will be found when these two incentives exactly match one another. Differentiating the maximization problem [5] will also allow us to determine this T*.

$$dq(0)/dT = e^{-rt}P'(T) - rP(T)e^{-rt} \qquad [7]$$

The first term represents the price effect that is the motivating factor in the extension of growing time (harvest postponement). The second term represents the discounting effect that entices impatience, decreasing the growing period (earlier harvesting). Rearranging and simplifying yields:

$$P'(T^*)/P(T^*) = r \qquad [8]$$

This is equivalent to the earlier, graphical result and solves the problem posed by [5]. This solution, although in line with Irving Fisher's "Theory of Investment" model[11], contains a bold assumption that the land that hosts the existing trees has no alternative use. By expelling this assumption Philip Neher develops an accurate model of a continuous forest.

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[11] Fisher (1930)

Continuous Harvest:

The inclusion of an infinite sequence of harvests as apposed to a single crop will be characterized by a shorter rotation period. This comes as a result of there now being an opportunity to replace the old, slow-growing trees with younger trees, whose value grows faster. In order to maintain an economically efficient model, this opportunity needs to be exploited.

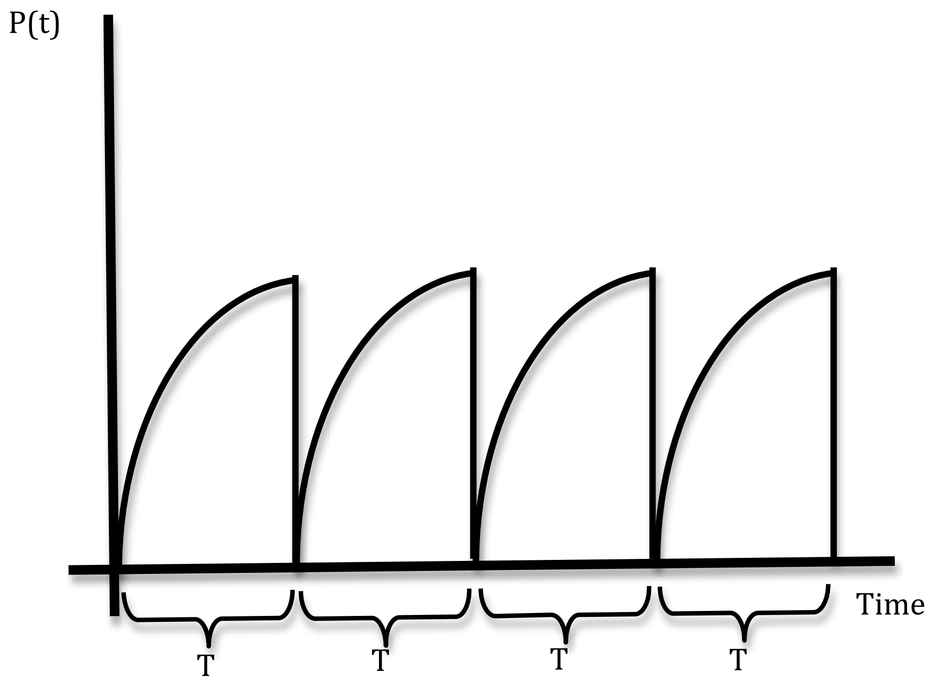

Figure 3: A sequence of harvests

Figure 3 graphically illustrates a sequence of harvests given a rotation period (T) that is yet to be decided upon. This pattern is simply a sequence of P(t) relationships, shown previously in figures 1 and 2, stacked beside each other from left to right. Determining the rotation period that maximizes the present value of a sequence of tree stands requires the summation of each trees present value, which is given by the present value maximization problem previously stated in [5] where the trees cut on the second rotation are to be sold at 2T years, the trees on the third rotation sold at 3T years, and so on. Summing these values together, the objective is to choose T to:

$$\text{Max } Q(0) = P(T)e^{-rT} + P(T)e^{-r2T} + P(T)e^{-r3T} + \ldots, \qquad [9]$$
$$= P(T)(e^{-rT} + P(T)e^{-r2T} + P(T)e^{-r3T} + \ldots,)$$

The assumption here is that the sequences of harvests will continue indefinitely, with the price of trees P(t) assumed to be unchanged as well. Observing that the term in the brackets is a declining, infinite, geometric series that has a finite sum allows us to reformulate the equation:

$$\text{Max } Q(0) = P(T)[1/(e^{-rt} - 1)] \qquad [10]$$

The right hand side of the equation can be thought of as an annuity, worth a fixed amount (P(T)), paid forever, at intervals of T years with continuously compounded interest at the rate of r. The maximization problem derived above allows for the selection of a rotation period in which the value of each tree is maximized given a sequential harvesting pattern. Differentiating this problem with respect to T gives the result again that the value of Q(0) at first rises then falls as T increases.

$$dQ(0)/dT^{**} = [(e^{rT^{**}} - 1)P'(T^{**}) - P(T^{**})re^{rT^{**}}]/(e^{rT^{**}} - 1)^2 \qquad [11]$$

Multiplying both sides by $(e^{rT^{**}} - 1)^2$ yields:

$$P'(T^{**})/P(T^{**}) = r(e^{rT^{**}}/e^{rT^{**}} - 1) \qquad [12]$$

This is the solution to our maximization problem posed by [10]. We can then rearranged [12] in order for it to be more easily compared with [8].

$$P'(T^{**})/P(T^{**}) = r(1/1 - e^{rT^{**}}) \qquad [13]$$

The comparison of equation [13] to equation [8] verifies the intuition that cutting time is shorter when repeated rotations are used rather than a single harvest. This conclusion is drawn from the fact that

$$[1/1 - e^{-rT^{**}}] > 1$$

Which is true if

$$e^{-rT^{**}} > 0$$

and it is. As a result, T** is less than T* in [8]. Therefore, the trees will be younger and faster growing in their stumpage value along an optimal path if our forester optimally plans for continuous future harvests. The interpretation of this result is that the rotation period (T) needs to be selected so that the capital gains (P') are large enough to cover the financial opportunity cost of leaving the trees in the ground, plus the present and future rental value of the site itself.

Comparison of Results:

It is interesting to see that a single resource problem will give rise to three distinctly different solutions. As accurate time-to-cut decisions will become ever more important as forest use increases, understanding how the three different times to cut compare is therefore important. The three solutions derived by Neher are:

Maximum Sustained Yield

$$P'(T^M)/P(T^M) = 1/T^M \qquad [3]$$

The Single Harvest

$$P'(T^*)/P(T^*) = r \qquad [8]$$

Continuous Harvest

$$P'(T^{**})/P(T^{**}) = r(1/1 - e^{rT^{**}}) \qquad [13]$$

It has already been determined that T* > T**. As the solution T* is most appropriate for single crop harvests, it is not a realistic solution for any present day forestry industry and is therefore strictly dominated by T**. As a result we can dismiss the single harvest solution. The comparison that needs to be made is the one between the maximum sustained yield and the continuous harvest solutions. These are comparable as they both apply to settled sustained-yield conditions. The only real difference is that the continuous harvest solution includes an interest rate where the maximum sustained yield does not. Although both these solutions seem theoretically viable in certain situations, their real life application has yet to be thoroughly tested. Canada provides a perfect setting to test Neher's model. Its vast forest industry has contributed to the country's economic growth for decades without creating any sort of natural resource curse. As a result, it seems like an ideal example to support Neher's model. The following sections will provide an empirical analysis of Neher's model, sighting Canadian forests as the case study in which to test his continuous harvesting solution. This is the ideal solution to empirically examine because it links harvest yields to the economic determinants of net price as well as the interest rate. Neher's maximum sustained yield solution ignores the interest rate and only links harvest yields to the determinants of net price. As a result, the maximum sustained yield solution will also be ignored during the empirical tests, as it may not provide a realistic example of the economic conditions present in Canadian forest manufacturing. However the relevance of both the maximum sustained yield and continuous harvest solutions will be revisited following the empirical tests.

Empirical Work

Neher's continuous harvest model suggests a correlation across time between the percentage change in harvest yields, and the percentage change in the price received from a harvest (WPI) and the interest rate (IntRate) available on alternative assets. However, Neher's model implicitly allows for the inclusion of other possible economic variables that are determinants of the net price received for timber. The inclusion of these additional variables will allow for a more accurate analysis of Neher's optimal continuous harvesting strategy. Including a measure of total factor productivity (TFP) will allow for technology effects to be represented within the model. These technology effects could include advancements to machinery that would allow for a decrease in the time it takes to harvest one single timber stand. In addition, labour productivity (Q/L), although closely related to TFP, would capture other effects outside technology advancements such as the quality of labour available and would allow us to depict how knowledge and skill improvements affect harvest choices. As the Canadian forestry industry is a large exporter of timber products, a measure of the Canadian exchange rate (CUX) could also improve the empirical analysis of Neher's model. Gross National Product (GNP) needs to be included in order to capture the macro-economic conditions in the economy. Since Neher's model uses the net price of wood, there are supply and demand forces present which effect how much timber is harvested each year. A measure of GNP will be able to capture these forces within the Canadian Economy. Furthermore, a measure of the available stock of timber each year should also show positive correlations with harvesting rates and therefore is included in the empirical model. Finally, including both a variable that represent the years (Year) which the data is from as well as a year^2 (Year^2) variable, should be a good proxy for any omitted variables that might have an effect on harvesting which cannot be represented by any of the other right hand side observations listed above. This would include anything that progresses in a linear or quadratic fashion over time such as climate change, urbanization and improvements in transportation.

When illustrated graphically, the three variables explicitly used by Neher's model seem to be unconditionally correlated with annual harvest yields. Figures 4 – 6 respectfully illustrate the unconditional relationship with annual Canadian harvest yields and the relative price of wood, the annual available stock of timber and the Canadian nominal interest rate. In all cases, as predicted by Neher's model, there seems to be a positive relationship with annual harvest yields, with the only noticeable deviation coming from the rapid decrease of the interest rate during the period of the Great Depression.

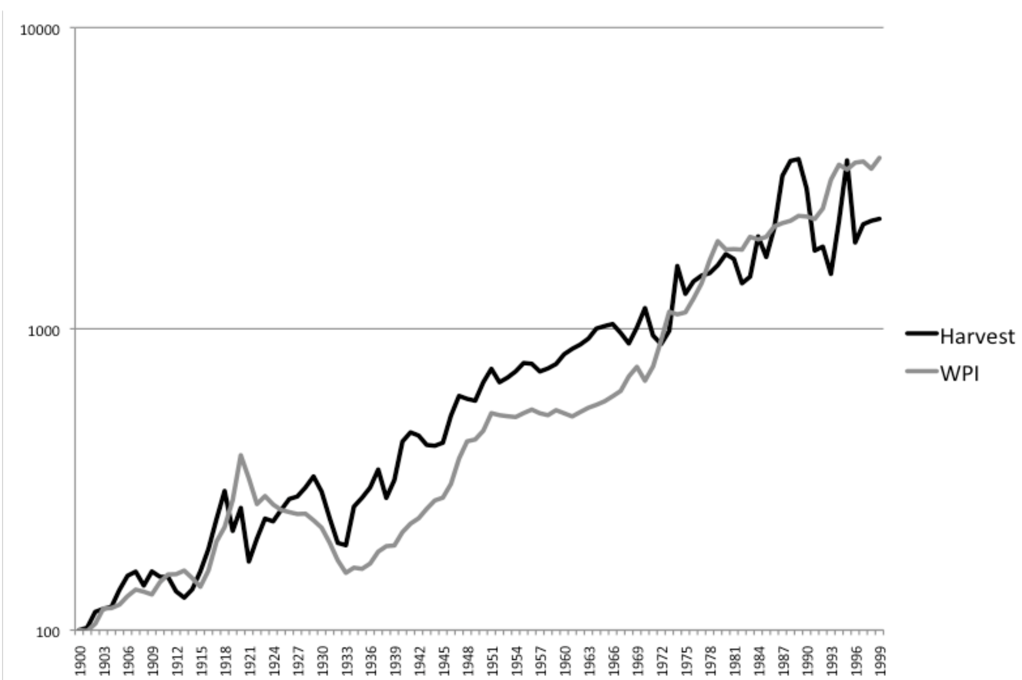

Figure 4: Annual Harvest Yields and Industry Price for Timber

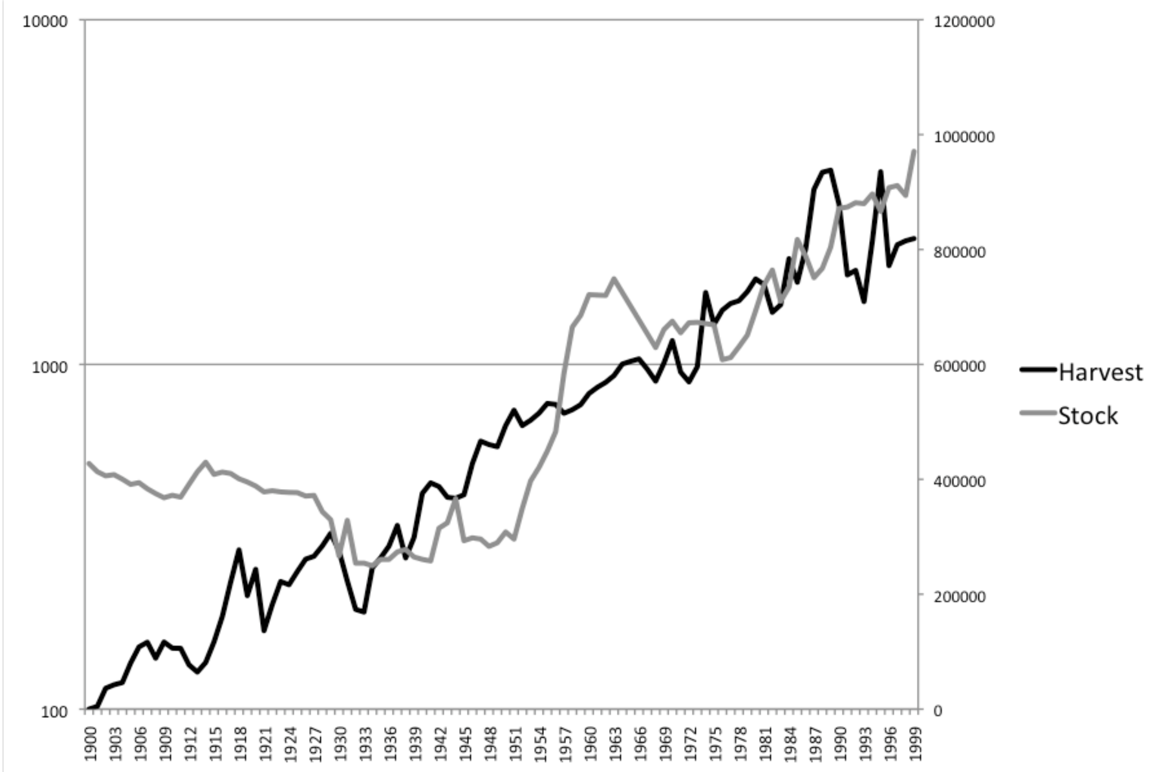

Figure 5: Annual Harvest Yields and Annual Available Stock of Timber

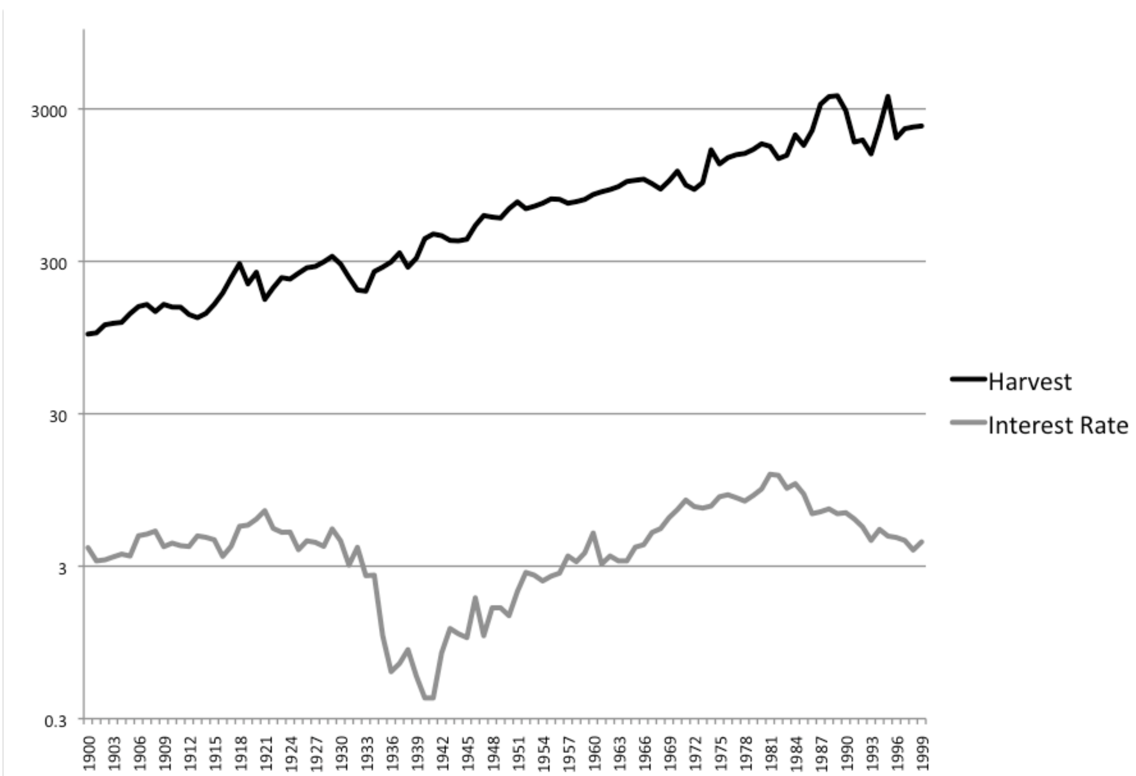

Figure 6: Annual Harvest Yields and Canadian Nominal Interest Rate

Although there seems to be some sort of relationship between these variables, formal regression analysis needs to be conducted in order to fully determine if any significant correlation is present.

Regression Analysis:

In order to establish if any of the previously stated economic variables have an effect on Canada's annual timber yields, I have performed a variety of regression exercises to test whether there is any significant correlation present. All regression testing has been done using the percentage change of the observed data in order to avoid any parameter estimate bias and to assure that all variables are stationary. The data set used contains 100 observations ranging between the years 1900 to 1999. This will allow for the inclusion of a variety of different economic time periods, which will enable us to examine a wide range of economic conditions in order to provide a more complete analysis of the historical accuracy of Neher's model. The first regression equation includes all variables throughout the entire time period so as to test the statistical significance of Neher's model over a large time frame. I then broke the observations into 4 distinct time periods: 1900-1929, 1930-1949, 1950-1971, and 1971-1999. This tested the possibility that a sustainable forestry model, such as Neher's, may be more suitable during certain economic conditions. Finally, to test the possibility that forestry decisions may in fact be based on economic conditions from past years I have included a lagged regression equation. This lagged equation includes all observed variables, however it places a one-year lag on the nominal interest rate, total factor productivity, quantity per labourer, GNP/capita, the

Canadian exchange rate and the relative price of wood. The parameter estimates (and standard errors) from the estimation of the above listed equations are displayed in Table 1. The results shown are, for the most part, contrary to Neher's continuous forestry model and show little correlation what so ever. There does not seem to be any overall statistical significance present in the all-inclusive regression and only small amounts of significance present in the other regressed equations. Nevertheless, there are a number of key results that should be discussed.

Table 1: Regression Results

	Equations					
Independent Variables	**All Inclusive:**	**1900-1929:**	**1930-1949:**	**1950-1971:**	**1972-1999:**	**Lag (t-1):**
WPI	.2989521 (.23939)	.9414405 (.4129145)	.442422 (.575312)	-.4745696 (.5011947)	-.4769205 (1.389282)	-.0398177 (.2462626)
IntRate	-.0442558 (.078874)	-.0358851 (.1634186)	-.1482265 (.064654)	.1237179 (.1158747)	.236408 (.6531863)	-.0763151 (.0814238)
TFP	.233886 (.2082426)	.9871846 (.3938512)	-.1184671 (.3510806)	.1461727 (.2674857)	.3264913 (1.078939)	-.4931295 (.2068858)
Q/L	.1680401 (.1251073)	.1856162 (.1712094)	-.3622162 (.1471968)	-.0576457 (.1589319)	.1043744 (.7485507)	-.4931295 (.2068858)
GNP	1.497438 (.3802591)	1.7679 (.5173592)	.0012307 (.5970016)	-.2398698 (.7330055)	6.734434 (2.655092)	-.0595014 (.3862616)
CUX	-.0091514 (.5236108)	-.7899611 (1.779226)	-1.62559 (.7001131)	2.233676 (.7533792)	.8220043 (1.395387)	-.1770064 (.5288792)
Stock	-.4908124 (.2491833)	-.9735978 (.8245214)	-.0528473 (.2270862)	-.4002414 (.3585608)	-2.236691 (1.239229)	-.3005065 (.2578385)
Year	.0097287 (.0873338)	-.9481371 (1.42954)	2.185132 (4.501581)	-2.674711 (1.952117)	4.060249 (3.580819)	-.0000219 (.0000237)
$Year^2$	-2.56e-06 (.0000224)	.0002478 (.0003734)	-.0005629 (.0011603)	.0006809 (.0004979)	-.0010218 (.0009011)	.085346 (.0925691)
R^2	0.1907	0.5863	0.7766	0.5878	0.4592	0.1375
N	100	30	20	22	28	99

Although the there is little significance in regards to the overall causation effects between the dependent and independent variables, there are a number of strong parameter estimates present as well as a few interesting correlations within certain time periods. The fact that there was no relationships present in the all-inclusive regression tells us that, on average, sustainable forestry practices in Canada have not been influenced, in the same way over time, by many of the previously argued economic factors. There is however some increased significance when the data is separated into the 4 different time periods. Although the total number of observations in these time periods is reduced, a case can still be made for the increased significance that is observed. By separating the data into more historically significant time gaps it allows us to examine the possibility of relationships existing as a result of the economic conditions present during that time period. These time-period equations in fact give some support towards Neher's model. Theoretically, there should be a stronger correlation within distinct time periods than across a wide range of economic cycles. As forester's decisions should be influenced by the economic conditions of their time, the harvesting yields they decide on would therefore be more correlated with the economic data within that time period. This is exactly what the results suggest. Although there is an increase in the significance levels from the all-inclusive equation, there still does not exits a strong relationship among the variables.

The most surprising result is that nominal interest rates show no correlation at all with annual harvesting yields. This is in direct conflict with Neher's theoretical depiction of a continuous forest. As a matter of fact, the parameter estimates on nominal interest rates show no statistical significance in all six of the regression results. It seems as though there exists no opportunity cost associated with the decision of harvesting earlier in order to invest in alternative assets. The results argue that the nominal interest rate is in fact irrelevant and has no observable impact on harvest rates. In fact, the results show that many of the other economic variables tested have a much stronger effect on timber harvesting than interest rates do. These findings support the notion that variables associated with net price have a greater effect on annual harvest yields in Canada than changes in the interest rate. This is exactly what we would expect to find if Canadian regulators were successfully using an approach similar to Neher's maximum sustained yield model rather than his continuous harvest solution.

As one would have assumed, the price of wood as well as available timber stock levels, both show a significant correlation with harvesting rates throughout all the regressions. Total factor productivity (TFP) as well as labour productivity (Q/L) both display positive correlations through all time periods except during the Great Depression era. The negative correlation seen in this time period is most likely a direct result of labour hording which was very common during the Great Depression as manufactures kept their workers employed however were not actually producing any goods. The results found for GNP and the Canadian exchange rate are for the most part not significant. The only noteworthy result is the strongly positive parameter estimate on GNP during the years 1972-1999. This is most likely a consequence of the oil shocks and subsequent efforts to control stagnation that took place in the 70's and 80's.

The primary conflicting result found was in regards to the insignificant effects of the interest rate on harvesting yields. This is in direct conflict with Neher's theoretical model of continuous forestry management and suggests that Canadian harvesting rates are simply not affected by the present day nominal interest rate. One of the main reasons for this result may be due to the structure of Canada's natural resource institutions. Canada has a long history of being a resource-intense country. As a result, its institutions have had time to grow and develop around this sector of its economy. With a large support network focused around Canadian resource exploitation, it may be the case that there doesn't exist any economically feasible substitutes for resource harvesting, such as investing capital in other assets. Looking back at table 1 we can see that over the four time-period regressions, the parameter estimate on the Canadian interest rate (IntRate) is slowly increasing (moving from negative to positive). The minor pattern that is shown supports the notion that a younger resource sector is more dependent on the availability of investing in alternative assets, due to the fact that the institutions associated with the young resource sector may be more volatile to economic cycles. As the resource sector matures, it becomes less dependent on investing in alternative assets in order to sustain profits. In other words, letting a tree grow for one more year becomes more profitable then cutting it down and investing the earnings. Furthermore, as the resource sector matures over time so to does the entire Canadian economy. A more stable economy means a less volatile interest rate. This allows foresters to better predict future rates of return on assets, enabling them to make better time to cut decisions. A less volatile interest rate, along with increases in growing and harvesting techniques, decreases the importance put on cutting early and investing. This may be another reason why Phillip Neher's theoretical model of a continuous forest cannot be practically applied to Canada's forestry sector.

Diagnostic Testing:

In order to maintain statistical integrity I have performed some general diagnostic tests. Firstly, some of the economic variables I use are closely related (TFP and Q/L for example), and therefore may exhibit signs of multicoliniarity. Testing for this produced some signs of correlation amongst my independent variables, however none were very significant. I proceeded by individually dropping these variables to make certain this correlation did not affect my results, which it did not. It is also essential that the data contain normal errors, predicting and regressing the residuals from my regressions showed that there was in fact error normality. Dickey-Fuller and Durbon-Watson tests were run to insure that the data was both stationary and did not exhibit any autocorrelation. Both tests came back negative. To test for heteroskedasticity I ran a White's test which also came back negative. Finally I tested the data for any outliers. Six of the one hundred observations came back as exhibiting some anomalies. These outliers came from the middle to later years of the data. After dropping these observations no significant changes to any individual parameter estimates or the overall results of the data were exhibited.

Summary and Conclusions

In this paper I have presented empirical evidence arguing that although Canada's forestry sector has successfully avoided the Natural Resource Curse, it has done so in a way that does not imitate Philip A. Neher's continuous harvest solution. Neher's model argues a set of regulations, policies and institutions that could help a nation avoid the resource curse. Although Canada has successfully avoided the resource curse, Canadian harvest techniques do not seem to exactly conform to Neher's model. In fact, the economic data on Canada's forestry industry is more closely related to the forest conservation policies established in the early 1900's. These sustainable forestry policies focused primarily on conserving the permanent forests throughout Canada, and did not entertain any policies allowing an economically efficient extraction of Canada's timber. As a result, the statistical data pertaining to Canada's forestry sector correlates much better with Neher's maximum sustained yield solution.

One of the main causes of the natural resource curse arises from the presence of institutional structures and policies that are unable to restrain the inefficient exploitation of renewable resources. As a result, countries require sound institutions that have the ability to exploit a country's resource endowments while constraining rent grabbing through economically efficient and sustainable regulatory practices. In Canada's case, the sheer mass and strength of the forestry sector has allowed foresters and regulators to focus primarily on maximizing the sustainability of Canadian forests as apposed to incorporating economic profitability into their policy regulations. It is this institutional strength which has allowed Canada to successfully avoid any symptoms of the natural resource curse without having to implement sustainable forestry policy's that involve maximizing profits in order to sustain the economic components of its resource sector. Instead, Canada's strong institutions have enabled it to focus its policies purely around creating a sustainable harvesting yield to allow for the maximum amount of forestry conservation.

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