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Department of Economics

Memorial University

+1 (709) 864-4089

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COLLABORATION FOR APPLIED RESEARCH IN ECONOMICS

THE GENERAL EQUILIBRIUM COSTS AND IMPACTS OF OIL PRICE SHOCKS IN NEWFOUNDLAND AND LABRADOR

Prepared by Robert Millard

Patrick Withey

Van Lantz

Thomas Ochuodo

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Abstract

We analyze the economic costs and impacts of a negative oil price shock in the magnitude of the 2014-2015 shock on the provincial economy of Newfoundland and Labrador, which is a region that is reliant on the oil and gas sector. We use a Dynamic Computable General Equilibrium (CGE) model to estimate a drop in oil prices by inputting the estimated effect as a direct impact to royalties, which are the land input in the oil and gas sector of the economy. A dynamic CGE model captures impacts across the entire economy (21 sectors) over a horizon of 30 years. We provide sensitivity to account for the magnitude of the shock, as well as the timing of recovery. The range of scenarios allows us to see how a drop in price of oil impacts economic indicators such as household consumption, income, factor input expenditures, and GDP. Our results suggest that a shock in the price of oil will have its most significant impact on GDP in the initial years. Over the first five years, the reduction in GDP due to this shock would be roughly 2.1% of GDP in our most realistic shock scenario, but could be much higher depending on the scenario considered. A sharp drop in GDP over the first five years will be mitigated in the long run as the growth in oil prices rises, however the will be some long run impacts due to the oil price shock.

1. Introduction

Oil prices have historically had a major impact on the global economy. Oil consumption has risen over the last 50 years, as nations have become reliant on oil for daily activities such as home heating, industrial processes and transportation. There have been few substitutes for oil, so shocks to oil prices can have a major economic impact. High oil prices in the 1970s led to inflation and had severe negative impacts on many countries in the world. This caused oil importing nations to re-examine energy security, and resulted in movements towards energy efficiency and the development of alternative energy sources. On the other hand, when oil prices drop, oil producing and exporting countries face a reduction in revenue streams, which can lead to economic downturns. Given the impact of oil price fluctuations, oil price shocks have been the focus of a great deal of study since the shocks in the 1970s.

While oil prices were high for much of the early 2000s, prices declined sharply in the summer of 2014 to levels that were less than half of their 2012 values. The West Texas Intermediate (WTI) spot price for crude oil was $105 per barrel as of July, 2014 and by January, 2015 it had dropped to 44 $/barrel. Prices recovered marginally until May 2015, but have been steadily declining since then. In February 2016, WTI prices reached their lowest point of 26 $/barrel (Federal Reserve of St. Louis, 2016). Canada is a major player in the global market for oil and gas; proven reserves in Canada are third in the world, while production and exports are fifth and fourth, respectively. Further, the oil and gas sector accounted for 7.5% of Canadian GDP in 2013. [1] Given this dependence on the oil and gas sector, it is clear that shocks to oil prices may have hard hitting and potentially long lasting effects on the national economy. With a lower value of Canadian production and exports, Canada suffers a loss of international purchasing power. The drop in terms of trade is felt through a reduction of GDP and national income, which also increases unemployment and decreases government revenues (Royal Bank of Canada, 2014). The value of the

[1] http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/2014/14-0173EnergyMarketFacts_e.pdf

Canadian dollar also rose steadily with oil prices over the first decade of this century, and has depreciated in recent months following the 2014 price decline (Poloz, 2015).

The oil and gas sector is especially predominant within the provinces of Alberta, Saskatchewan, and Newfoundland and Labrador (NL). In NL, the Oil Extraction & Supporting Activities sector, comprised primarily of the offshore oil fields Hibernia, Terra Nova, and White Rose, is by far the largest individual contributor to GDP, responsible for approximately 30% of provincial GDP. Provinces such as NL, who saw great benefits from the rise of oil prices prior to the shock in the 2000s, have been the hardest hit when prices drastically fell. The shock to oil prices has resulted in increased unemployment, reduced production and GDP: "Production in oil and gas related industries declined by 8 per cent between the fourth quarters of 2014 and second quarter of 2015, while business investment linked to these industries fell sharply" (Bank of Canada, 2015). In NL, preliminary estimates show that there have been an estimated 2% drop in real GDP since 2014, an expected decline in production by about 16% as of 2015 and an increase in unemployment by about 0.6% in 2015 (Government of Newfoundland and Labrador, 2015). Further, the oil price drop has reduced government revenue (royalties); the NL government receives a significant portion of its provincial revenue (33%) from the various royalty regimes associated with the offshore oil extraction projects (Royal Bank of Canada, 2015).

Understanding the impact of a major change in oil prices on factors such as those described above can prove crucial for developing the optimal policy responses in reaction to shifting prices. Our goal is to estimate the short run (5 year) and long run (30 year) economic costs and impacts to NL from a drop in oil prices in the magnitude observed in 2014. To analyse this shock, we develop a dynamic Computable General Equilibrium (CGE) Model that has been calibrated to the NL economy. The model will track important economic variables like production, GDP, labour, investment, consumption, etc. across 21 sectors up until the year 2040. CGE models are useful in studying energy phenomenon as they can capture intertemporal movements throughout an entire economy, which is disaggregated into multiple sectors. Thus, these models can capture both direct impacts to the oil and gas sector, as well as indirect impacts in other sectors.

Many studies have examined how oil prices interact with the economy. Some studies examine how oil price uncertainty influences the Canadian economy. For instance, Bashar et al. (2013) used a structural Vector autoregressive model (VAR) to examine the relationship between oil price uncertainty and macroeconomic performance in Canada. They find that higher oil price uncertainty is linked to lower prices and output. Elder and Serletis (2009) also use a structural VAR model with two variables (oil price and output) and assess how uncertainty in energy prices can influence firms investment decisions and thus output in the Canadian economy. They found similar results, that increased oil price uncertainty is inversely related to “Canadian industrial production, output in goods producing industries and mining and oil and gas extraction”(Elder & Serletis 2009).

CGE models have gained momentum in the past few decades in analyzing energy phenomenon as they estimate the direct and indirect impacts of a variety of factors, under a range of scenarios, across multiple economic sectors. Researchers can manipulate variables of interest and follow how the rest of the economy (multiple economic sectors) adjusts in response to specific shocks. A popular adjustment in energy related models targets specific commodity prices. For instance, Solaymani et al. (2015) apply a CGE model to analyse the economic and environmental consequences of energy subsidy adjustments on the Malaysian economy. Removal of these subsidies will lead to cost increases for different sectors, with the same result as an increase in oil prices. They investigate impacts from 3 scenarios: high oil prices, energy subsidy reforms, and a combination of both. Their findings show that each shock, which are all representative of a positive shock to oil prices, are beneficial to overall economic performance, and subsidy reform is detrimental to household consumption and welfare. Higher oil prices raise real GDP and household income, stimulate investment, and increase Malaysian terms of trade in the long run. The higher prices lead to a reallocation of resources into oil producing sectors as these sectors benefit from increased value of oil caused by the shock.

Aydin and Acar (2011) examined the general equilibrium impacts of a change in oil prices, focusing on GDP, the CPI, tax revenues, trade flows, and carbon emissions. The model they used was called TurGEM-D, which is a multi-sectorial dynamic model suited for the Turkish economy, a small open net oil importing country. Their oil price scenarios include low, reference, and high oil prices. Their results shows that high oil prices led to reductions in output and consumption, however they also found that the higher prices reduced carbon emissions. Canada, a net exporter of oil, would likely gain from higher oil prices, as the value of production rises with prices.

Dybczak et al. (2008) examine why the rapid increase in oil prices had such a small impact on the Czech economy. They implement a structural CGE model and statically shock the representative Czech economy under different scenarios that vary in terms of changes in oil prices and future energy intensity. The shock results in increased prices and decreased competitiveness domestically and in foreign markets, leading to increased unemployment. Bargaining power falls with employment and drives down real wages. With lower factor prices, firms increase production and reduce prices, restoring competitiveness and bringing up employment and production. They found that Czech Republic, a net oil importer, reduces dependence on oil thus mitigating the impacts.

Doroodian and Roy (2003) use CGE modeling to assess how a rapid increase in the price of oil, in the magnitude of that observed in 1973-74, influences inflation of the US dollar. The shock was felt in the economy though changes in factor prices and prices of consumption goods. Doroodian and Roy found that the sectors hit hardest were energy related sectors, specifically from large increases in gasoline and refinery prices. They found that the inflationary effects from the shocks eventually dissipated over time, and even more so as technology advanced.

CGE models are a diverse and well established tool used to examine changes in oil prices or energy policy in a variety of contexts. In the current application, we use a multi-sector dynamic CGE model for the province of NL. We examine the impact of a decrease in oil prices, similar to many studies in the past that examined the impact of higher prices. In the current application, we model oil price reductions as a reduction in royalties (the land input in the oil and gas sector). We follow this route since land inputs are exogenous in the model, and shocking royalties will allow us to capture the reduction in the productive capacity of the oil and gas sector due to lower prices. Further, we can include a verity of scenarios for price growth via exogenous growth in royalties over time, allowing us to capture intertemporal impacts.

2. METHODS

CGE Model Specification

We use a provincial, recursive dynamic CGE model for the economy of Newfoundland and Labrador (NL). The model is based on neoclassical economic theory. The specification for our model follows that of Ochuodho and Lantz (2014) and Corbett et al. (2015). However, our calibration differs as we use baseline 2009 economic data for NL and focus on shocks to the oil and gas sector. For more details on the model, refer to Ochuodho and Lantz (2014).

NL is assumed to be a small open economy that operates under perfect competition. Producers are assumed to maximize profits (defined as the difference between revenue earned and the cost of factors and intermediate inputs) subject to constant returns to scale on production technology. There are three primary factors of production in the model: labour, capital, and land in the oil and gas sector (i.e. royalties). The production function for firms is specified in a two-level nest. At the top level, a composite of value-added and a composite of intermediate inputs are smoothly substitutable in a constant elasticity of substitution function (CES). At the bottom level, the three primary factors of production are assumed to substitute smoothly through a CES composite value-added function under single primary factor nest (Rutherford and Paltsev 2000; Winchester et al. 2006). Intermediate inputs, on the other hand, are determined by fixed-shares through a Leontief function.

There is a representative household who aims to maximize utility through consumption. The household receives income by supplying factors of production and from import tariff revenues transferred to them by their domestic governments (Prasada et al. 2010). Supplies of factors of production are typically assumed to be fixed within a given time period. Labour and capital are mobile across sectors, whereas royalties are specific to the oil and gas sector. Under the capital mobility assumption, firms could move their capital from one industry to another in response to different rental rates in the economy (Alavalapati et al. 1998).

Household savings rate is determined by a fixed marginal propensity to save; a fixed proportion of total income is saved. Disposable income is total household income less savings, which is spent on consumption. The optimal allocation between consumption of commodities by households is through maximization of a Stone-Geary utility function (a Linear Expenditure System (LES)). LES is structured so that expenditure has a linear relationship with income and price, and is thus maximized subject to the household's disposable income constraint.

Total savings is the sum of household and foreign savings. Investment demand is determined by total savings factored by Cobb-Douglas investment preference for each commodity. Unemployment is endogenous to the model, specified with a Phillips curve. This explains the relationship between wage and unemployment using a Laspeyres consumer price index (CPI) and factor prices and supplies.

Input factor supplies are exogenously determined in the model, based on existing data. Equilibrium in the factor markets requires that the demand for factors equal the supply. To achieve equilibrium, factor prices in these markets must adjust to ensure that demand equals supply. However, unemployment (voluntary and involuntary) exists due to imperfect labour markets. Therefore, market clearing for labour is relaxed to allow for unemployment in labour supply.

NL, as a small open economy, differentiates traded products according to their region of origin. That is, all goods in the model are either produced domestically or imported. Domestic consumers discriminate between domestically produced and imported goods through a CES Armington specification (Armington 1969). The final ratio of imports to domestic goods is determined by the relative prices of each type of good as domestic demanders seek to minimize their costs. Thus, an increase in the domestic-import price ratio causes an increase in the import-domestic demand ratio. In other words, demand shifts away from the more expensive source. On the supply (export) side, the domestic outputs delivered to domestic market are differentiated from products produced for export by the same sector. So, substitution possibilities also exist between production for domestic and foreign markets. Producers make this decision through a constant elasticity of transformation (CET) function, which distinguishes between exported and domestic goods. As profit maximizers, producers sell in those markets where they can achieve the highest returns. This condition ensures that an increase in the export-domestic price ratio causes an increase in the export-domestic demand ratio. Thus, demand shifts to the higher return source.

Model Calibration

The model was calibrated to the NL economy using 2009 symmetric IO tables produced by Statistics Canada (Statistics Canada, 2011a, 2012). The provincial economy was aggregated in to 21 sectors at small (S-level) aggregation following the Northern American Industry Classification System (NAICS 2002 version).

Three primary factors of production were specified, including labour, capital, and land (royalties in the oil and gas sector). Labour was measured (using Statistics Canada IO tables) as wages, salaries, and supplementary labour income, in addition to 'mixed income' (i.e. income of unincorporated businesses). Capital was measured (also using Statistics Canada IO tables) as the sum of other operating surplus, indirect taxes on products, subsidies on products, other subsidies on production, and other indirect taxes on production less land services expenditures (in the oil and gas sector only).

Royalties are the payments that firms make to government for the use and development rights of land used in oil extraction and production. Thus, royalties are specific to the oil and gas extraction sector of the NL economy. Royalties are reflective of the value of productive land inputs in the oil and gas industry and are modelled as general payments producers make on land inputs. Larger royalties indicate larger payments on land inputs, implying enhanced productive capacity. Royalty values were taken from NL Provincial accounts, using data between 2004-2014 (Government of NL, 2016). Note that while the model estimates shocks of the magnitude observed in 2014, the model is actually calibrated in the base case using 2009 data (most recent at time of model development), and the analysis is conducted over the 2009-2040 period. However, royalties in 2009 in NL, as well as the average annual royalty over the 2009-2014 periods are similar to royalties in 2014. Thus, we believe that the model will capture royalties (and shocks) in a reasonable way for our purposes. Royalties were added in the oil and gas sector, and the amount was taken out of capital in that sector.

Parameters were estimated so as to accurately reflect the economy of NL in the base year. Elasticity parameters, including income elasticity, elasticity of substitution, and elasticity of transformation, were derived from other studies (Dimaranan 2006) or using Statistics Canada IO data (Corbett et al. 2015). The model is first solved statically given the input-output data. The initial equilibrium represents the benchmark state of the NL economy in 2009. Following this static general equilibrium, the model is solved recursively over a 31-year (2009-2040) time period. For every period, capital stock was updated via a capital accumulation equation based on an endogenous growth rate as determined by endogenous return on capital rate and endogenous total saving (Ochuodho and Lantz 2014). Labour was assumed to grow at an exogenous rate in the model. Labour supply growth projections were estimated using projected employment data from Statistics Canada (Statistics Canada 2011b). All the values are in real terms, with 2009 as the base year, and the discount factor used for all present value calculations is 4%. Growth of royalties is assumed to be exogenous and to follow the same growth path as oil prices, based on EIA projections. We calculate the growth rate based on the reference oil price scenario in Energy Information Administration (EIA) (2013); this growth rate represents a change in prices between the shock period (2014) and 2040. For the baseline scenario, we calculate the growth rate in prices based on the pre-shock oil price ($93 per barrel) and the price of $265 per barrel in 2040 (EIA, 2013). We assume that royalty growth follows the same growth as oil prices. We use the 2013 publication from EIA, as this oil price forecast was produced prior to the shock. Our baseline model assumes no price shocks, so price forecasts should not include information after the shock. Note that assuming royalties follow the same growth path as oil prices is a simplification, as the value of the royalty payments are dependent on a structure of production targets, and different net tier payments based on net profit structures and return allowance.

Model Solution and Oil Price Shock Scenarios

The model equations were solved using the General Algebraic Modeling System (GAMS) software with a nonlinear programming algorithm along with CONOPT3 solver (GAMS, 2012). The model is first solved for the initial period to replicate the 2009 benchmark IO tables. Then, a dynamic baseline growth path for the economy was simulated in the model by allowing labour, capital, and royalties to grow as described above. Economic variables in the baseline scenario can then be compared to those under other scenarios (or growth paths) related to adverse shocks to royalties. This allows for assessment of the economic costs and impacts of reduced oil prices.

To model the impact of oil price shocks on the provincial economy, we used five scenarios that capture the decrease in oil prices through reduced royalties. Again, we model a shock as reduced royalties and not prices directly, as royalties are exogenous in the model, and we are able to simulate growth in royalties over time. In this way, we directly impact the productivity of the oil and gas sector, as the value of production will fall as the land input falls. For all royalty shock scenarios, we adjust the royalty growth rate following the shock, so that royalties (i.e. oil prices) will return to their predicted 2040 value as given in the 2015 (EIA) Annual Energy Outlook. Unlike the baseline, which relied on a 2013 (pre-shock) EIA price forecast, we use the most recent 2040 oil price forecasts to model the growth or royalties following the shock. Following the shock, royalties will grow at a faster rate in order to achieve the 2040 levels. However, long run impacts may still result, due in part to the initial shock, and in part because the 2015 price forecast is lower than the 2013 price forecast ($220 vs. $265 per barrel for the reference scenario by 2040). An example of how we calculate oil price growth, and thus royalty growth rates is provided in Table 1.

Table 1: Oil Price Forecasts

2013 Forecast (pre 2014 oil price drop)			**2015 Forecast (post 2014 oil price drop)**		
2013	**2040**	**Annual growth**	**2015**	**2040**	**Annual growth**
$93	$265	4.1%	$48.96	$220	6.22%

Sources: Energy Information Administration (2013; 2015)

We consider a variety of scenarios, in an attempt to try and understand the impact of the oil price drop, given a variety of shocks and recovery options. Scenario 1 assumes a 50% reduction in royalties in the first period. We assume that production remains constant during the one-period shock. Scenario 1 serves as our main shock scenario, and is based on the observed reduction in (average annual) oil prices from 2014 to 2015; average WTI prices per barrel were $93.26 in 2014 and $48.69 in 2015. Following the one period shock, royalties being to grow at a rate of 6.22% (see Table 1).   Scenarios 2 -5 are included for sensitivity and robustness. Scenario 2 assumes a one-time, 75% decrease in royalties in the first period. This implies a larger impact to the value of production from the same magnitude oil price shock as Scenario 1, due to potential reductions in the quantity of oil produced. A worst case scenario is represented by Scenario 3. We decrease royalties by 90% in the first period, describing a scenario in which the oil and gas sector experiences a near total productive shutdown. Scenarios 1 through 3 involve only single period declines in royalties. Scenarios 4 and 5 differ as they incorporate two-period royalty shocks. This is necessary, as we are now into the second year (2016) without any recovery in oil prices. In the first period, there is 50% decrease in royalties and in the subsequent second period, we impose a further 20% drop. In Scenario 4, we assume that price levels recover gradually following the shocks. That is, they grow at a constant rate back to the 2040 levels, as in the other scenarios. Scenario 5 allows for prices to recover immediately after the second period shock. That is, for Scenario 5, the NL economy recovers to price levels equal to those directly before the shock, and then grows to the 2040 levels (at a slower pace). The royalty growth rates in each of the baseline and shock scenarios are provided in Table 2.

Table 2 Shock levels and oil price growth rates for baseline and shock scenarios.

Scenario	Shock to Royalties	Royalty Growth rate (%)
Baseline	-	4.10
1	50%	6.22
2	75%	9.4
3	90%	13.48
4	50+20%	9.38
5	50+20%	3.8

Note that we capture the general equilibrium impact of lower oil prices by capturing the reduction in the value of production in the oil and gas sector. Results are measured primarily in terms of reduced GDP, compensating variation, production, income, consumption, etc. However, we do not capture the impact of higher unemployment (since there has not been a large rise in unemployment in NL from 2014 to 2016), or reduced Government Revenue (royalties). That is, in this application, royalties are the value of inputs into production in the oil and gas sector, and not revenue for government. We leave these other elements for future study.

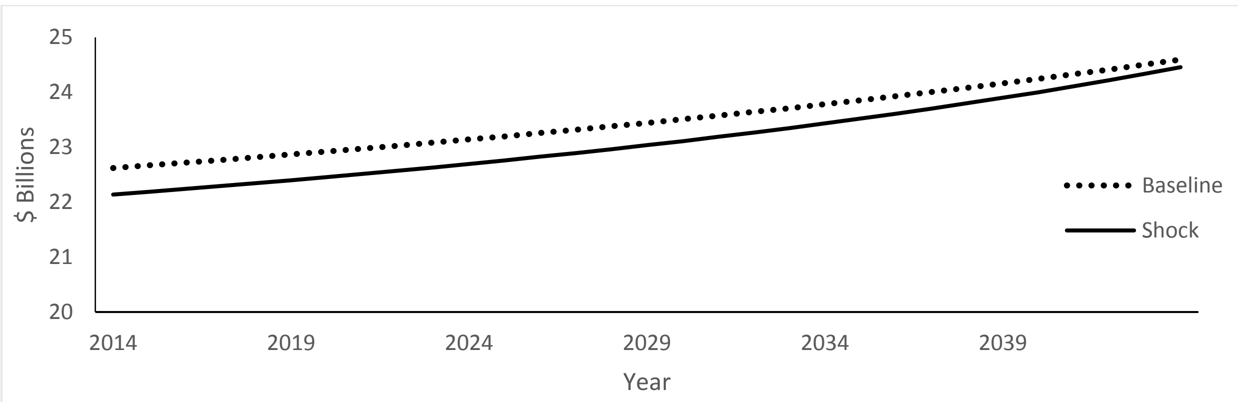
3. RESULTS

Impacts of Oil Price Shock in the Long Run

We first examine the impact of the drop in royalties on economic variables in the long run, focusing on the Baseline model vs. Scenario 1. The Baseline scenario and Scenario 1 growth paths for GDP are presented in **Figure 1.** Over the 2009-2040 period, GDP was lower due to the negative shock to royalties. In the Baseline scenario, the economy accumulated approximately

$409.89 billion (present value) of GDP over the time horizon. The effect of the 50% royalty decrease in the first period was stronger in the short-run, as the economy converged back to the baseline in later years due to the fact that prices are thought to largely recover by 2040. This is captured in the model by the fact that our royalty growth rates are higher following a shock.

Figure 1: Long-run GDP growth path for Baseline and Scenario 1.



In Table 3, we summarize these long run impacts by presenting cumulative present value estimates for Scenario 1 and the Baseline. Economic costs (i.e. reductions in compensating variation) and impacts (i.e. changes in GDP, income, consumption, investment, export, import, and input expenditures) due to oil price shocks were estimated by calculating the difference between the respective variables under the baseline vs. shock scenarios. All values were presented in 2009 Canadian dollars, over the 2009-2040 period, using a 4% discount rate. As a result of Scenario 1, NL GDP was estimated to fall by $7.12 billion in present value terms over the 30-year period, or roughly 1.74%. This impact occurred because of the initial shock, and due to the fact that prices do not recover completely (to levels forecasted prior to the shock) in 2040 following the shock. Economic impacts were captured in the model by a reduction in production (and thus income) in the oil and gas sector when royalties fall, which ultimately impacts consumption and investment. Scenario 1 caused a decline in the 30-year cumulative values of production (0.74%), household income (1.77%), consumption (1.30%), investments (1.59%), and labour expenditures (1.90%). Welfare impacts (as measured by compensating variation) were a loss of $4 billion.

Table 3: Baseline vs. Scenario 1 values (cumulative present value $Billions; 2009-2040).

Variable	Baseline	Scenario 1	Difference	% Change
Gross Domestic Product	409.89	402.77	-7.12	-1.74
Household Income	419.36	411.93	-7.43	-1.77
Household Consumption	311.23	307.19	-4.04	-1.30
Investments	84.93	83.59	-1.34	-1.58
Labour Expenditures	211.48	207.47	-4.01	-1.90
Royalties	70.88	49.11	-21.77	-30.71
Compensating Variation	4.6	0.6	-4.0	-86.96
Domestic Production	664.2	659.3	-4.9	-0.74

Oil Price Shock in the Short Run

We focus the remainder of the analysis on short run impacts. Short-run analysis provides insights into how the NL economy adjusts immediately following a shock, or when the impacts are the largest. This is deemed to me more interesting in this analysis, since by design, the prices will largely recover in the long run, based on pre and post-shock oil price forecasts by EIA. Since we capture this in the royalty growth rates, the impacts in the long run are likely to be lower than short run impacts.

In the first year following the Scenario 1 shock, $464 million is GDP was lost in comparison to the Baseline scenario. The impact in the second year was lower, as we observed a drop in GDP of $444 million relative to baseline. **Table 4** presents the five-year cumulative impacts of Scenario 1 relative to the baseline for key economic indicators of interest. The difference in 5-year cumulative GDP was $2.13 billion. The percentage change for 5-year cumulative GDP (2.1%) was larger than that for the 30-year horizon, which indicates that the difference between Baseline and Scenario 1 was larger in early years, and became smaller as time passed after the initial shock. This is not surprising as prices are assumed to recover over time. All other key variables fell in similar magnitude to GDP in the first five years.

Table 4: Five-year impacts of Scenario 1 vs. Baseline (cumulative present $Billions).

Variable	Baseline	Scenario 1	Difference	% Change
Gross Domestic Product	101.12	98.99	-2.13	-2.1
Household Income	103.40	101.18	-2.22	-2.15
Household Consumption	77.23	76.10	-1.13	-1.46
Investments	20.99	20.60	-0.39	-1.88
Labour Expenditures	52.08	50.83	-1.25	-2.41
Royalties	12.72	6.66	-6.06	-47.7

Sensitivity: Shock Magnitude

In Scenarios 2 and 3, we explore short run impacts, assuming the shocks are larger than expected. Scenario 2 is meant to capture a scenario where production (quantity, not just value) is also significantly impacted, and Scenario 3 considers a worst case where production almost ceases to exist for one year. These scenarios are for the purposes of sensitivity, as such circumstances have not come to pass in NL. As expected, the short-run impacts of Scenarios 2 and 3 are greater than that of Scenario 1. That is, the larger the shock to royalties, the larger the impact on GDP and other economic indicators. **Table 5** presents five-year cumulative impacts for Scenarios 2 and 3. For Scenario 2, we see that a 75% decline in royalties caused GDP to fall by $20.52 billion from the Baseline scenario. Scenario 3 had an even larger impact on GDP, causing a $26.08 billion loss over five years. Household income, consumption, labour expenditure, and royalties show consistent results; the larger the magnitude of the shock, the larger the adverse effect on each variable.

Table 5: Five-year cumulative impacts for Scenarios 2 and 3 and percent change from Baseline (cumulative present value $Billions).

		Scenario 2		Scenario 3	
Variable	Baseline	Total value	% Change	Total value	% Change
Gross Domestic Product	101.12	80.59	-20.30	75.04	-25.79
Household Income	103.40	82.39	-20.32	75.28	-27.20
Household Consumption	77.23	61.98	-19.75	58.86	-23.79
Investments	20.99	16.17	-22.96	17.55	-16.39
Labour Expenditures	52.08	44.24	-15.05	43.99	-15.53
Royalties	12.72	3.71	-70.83	1.68	-86.79

It is interesting to note that the general equilibrium impacts for NL estimated in our Scenario 1 are comparable to preliminary estimates of a 2% drop in real GDP since 2014 (Government of Newfoundland and Labrador, 2015). The impacts in Scenario 2 and 3, while interesting for sensitivity and to illustrate potential worst case scenarios, are not consistent with what has been observed. Our Scenario 1 does seem to be capturing the impact reasonably well, based on observed data. The five year cumulative impact of 2.1%, and one year impact of 2.13% (not shown above) are in line with that 2% impact. The additional advantage to this analysis is that we capture the impact on several other variables of interest and also capture long run impacts. Further, and given confidence about initial results, we consider the short run impacts of a prolonged shock in year 2, as well as different patterns of re-growth.

Sensitivity: Shock Duration

Scenarios 4 and 5 capture shocks in the first two years following the price decline. In period one, royalties fall by 50%, as in Scenario 1, but in year two, royalties fall by an additional 20%. These two-period shocks to the model aim to reflect the current situation in the oil market. The difference between the two scenarios is that in Scenario 4, royalties gradually rise to 2040 levels following the shock, as in Scenario 1, whereas in Scenario 5, we assume royalties recover instantly to pre-2014 levels, and then grow at a slower rate (than Scenario 4). Impacts are the same in years 1 and 2 for Scenarios 4 and 5: in the first year, GDP fell by $495 million from the baseline. The loss in the second period was $754 million. Impacts began to differ in the third period. As expected, the short-run (five year) impacts for Scenario 4 were greater because prices are not allowed to recover immediately following the shock. However, in both cases of persistent shocks, cumulative five-year impacts were greater than that of a single-period 50% decline in royalties (Scenario 1). Scenario 4 resulted in a $3.04 billion decline in GDP from the baseline scenario, whereas Scenario 5 resulted in a $2.69 billion loss. Table 6 presents the five-year cumulative impacts of the persistent shocks on GDP and other variables of interest. Household income, investment, consumption, labour expenditure, and royalties show consistent impacts: gradual price recovery resulted in larger economic impacts than immediate price recovery, but both scenarios led to higher losses than Scenario 1.

Table 6 Five-year cumulative impacts for Scenarios 4 and 5 and percent change from Baseline (cumulative present value $Billions).

		Scenario 4		Scenario 5	
Variable	Baseline	Total value	% Change	Total value	% Change
Gross Domestic Product	101.12	97.82	-3.26	98.44	-2.65
Household Income	103.40	99.96	-3.33	100.62	-2.69
Household Consumption	77.23	75.52	-2.21	75.44	-2.32
Investments	20.99	20.39	-2.86	20.47	-2.48
Labour Expenditures	52.08	50.12	-3.76	50.79	-2.48
Royalties	12.72	4.21	-66.90	8.80	-30.82

The short run results found in Tables 4 and 6 are reasonable, based on observed impacts in the last year (as mentioned above), and expectations on what might occur. Results will clearly be impacted by the length of the shock, changes in production levels, length of recovery and the subsequent growth rate in prices. For instance, if prices were to remain low for the next three years, the results presented here would surely be an underestimate of actual impacts. However, this analysis provides potential impacts for a variety of scenarios related to the magnitude of the shock and timing of the shock and recovery, which provide a reasonable range of impacts that can be expected.

4. Discussion and Conclusion

We used a dynamic, 21 sector CGE model of the NL economy in order to examine the impact of a drop in oil prices of the magnitude witnessed in 2015. We considered a variety of scenarios related to the size of the shock, the timing of recovery, and future growth in prices. We found that a negative shock to oil prices (modeled through royalties, which is the land input in the oil and gas sector) can have hard hitting and long lasting impacts throughout the economy. The NL economy is heavily integrated with the oil and gas extraction and production sector. When oil prices decline, there is an immediate impact on the value of production in the oil and gas sector. This initial impact resonates throughout the economy, through reduced production, income and ultimately consumption. The impacts are revealed through GDP, household income, household consumption, investments, and labour expenditure, among other variables. While recovery in prices and increased growth will mitigate some of these impacts in the long run, the drop in oil prices will be felt for many years to come.

Our initial scenario showed that for a 50% one-year shock to oil prices, followed by faster growth in prices, there was a present value cumulative loss of $2.13 billion in GDP in the first 5 periods following the shock. Each of the other variables of interest suffered losses in similar percent magnitude, ranging between 1.88% to 2.40% difference between baseline and shock. The impacts estimated here are similar to those estimated by the Government of NL, which have examined impacts to date in NL from the shock.

The same shock also led to long run impacts over a thirty year horizon. GDP was projected to fall by roughly $7 billion over that horizon, or 1.74%. While the proportional impacts were less in the long run, we see that the shock could have long standing impacts, due to the size of the initial shock, as well as the fact that long run prices are projected to decline (relative to before the shock).

We also demonstrated that as the magnitude of the initial shock increased, the impact on GDP increased dramatically, which is not surprising. This demonstrates that the shock could lead to potentially damaging impacts, although this would require a reduction in production that has not been seen to date. We also considered the impacts to GDP in the short run if the shock lasts for a second year, and considered what would happen if prices recovery gradually vs immediately following this shock. These last two scenarios attempted to provide additional sensitivity, but also mimic the current oil price conditions. The cumulative 5 year loss in discounted GDP for each scenario was $3.30 billion for gradual recovery and $2.68 billion for full recovery. The percentage impacts on the other variables of interest were similar to the impacts to GDP. The adverse impacts were lower if prices recover quickly, which is intuitive. However, if the price drop remains for two years, the impact could be much higher than we have observed to date.

The various scenarios demonstrate that the reduction in oil prices that were observed in 2014 could have severe and long lasting impacts on the NL economy. This information is important for policy makers in the province, as an understanding of the magnitude of the impacts under different conditions will help policymakers to deal with the damages caused by the shock. Future work could deal with several limitations of the current work. First, we could potentially incorporate additional scenarios and sensitivities to our current analysis, to update the size of the shock, and allow for a prolonged low oil price scenario. Second, this analysis is limited by focusing solely on the impact due to the reduced value of production. We could also examine impacts to other areas directly affected by a rapid drop in oil prices, including scenarios that include increased unemployment. Further, we could add a government sector to the CGE model, and consider the impact of reduced revenue (through royalties) on the provincial economy. The NL governments received almost a third of its revenue from the royalties associated with oil production, thus changes to these streams of revenue can amplify the adverse consequences from a shock even further.

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