SHALE GAS EXPLORATION: POLICY ANALYSIS USING A COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR NEW BRUNSWICK

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Abstract

In this paper I review the economic and environmental controversies surrounding the shale gas industry and its growing popularity in North American markets. Specifically, I explore the potential economic benefits of exploration in New Brunswick, should the indefinite moratorium on hydraulic fracturing ever be lifted. I also discuss the various environmental concerns, but make no attempt to quantify these in the analysis. To estimate the economic impacts of shale gas exploration in New Brunswick, I simulate a shock to shale gas production over a 20 year period using a Dynamic, Computable General Equilibrium (CGE) model. The results of my model suggest that over a 20 year period, shale gas exploration would (approximately) add a cumulative $15 billion to GDP in New Brunswick.

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1. Introduction

Over the past few decades, exploration in the shale gas industry has emerged as both an economic prospect, and an environmental threat. Through hydraulic fracturing, oil and gas extraction companies have tapped into a new quantity of supply. Particularly so in North America, where the United States has been aggressively active. Canada also contains an abundant supply of shale gas; however, across the country many provinces are taking different stances on the matter due to environmental concerns.

New Brunswick has been estimated to contain a vast amount of natural gas within its underlying shale formations, and up until recently had begun to extract it through hydraulic fracturing. In 2014, a moratorium was placed on hydraulic fracturing by the Liberal Party of New Brunswick.

This paper endeavors to estimate the potential economic benefits of shale gas exploration in New Brunswick, should the moratorium on hydraulic fracturing ever be lifted. The paper is organized as follows:

Section 2 will provide background information on the history of shale gas and its progress in North America. It will go over what researchers currently know of the shale formations in Canada, and in particular, New Brunswick. Section 3 is an overview the structure New Brunswick's economy; its strengths and weaknesses, and some specific issues that are important in current context. It will then go over the many environmental concerns that have been raised so far, and how they affect the future of shale gas development.

Section 4 reviews the methodology and findings of previous studies on shale gas exploration. Section 5 provides insight to the theoretical concepts that are employed in our model, and goes over the specifications that we tune it with in order to properly represent the economic characteristics of New Brunswick.

Section 6 discusses the main findings of our research, and how they can be interpreted. And finally, Section 7 will conclude with a few points of discussion and a summary of our findings.

2. Background

2.1 Advances in North America

Since the formation of the Organization of the Petroleum Exporting Countries in the late 20th century, modern society has developed a knee-jerk reflex in which we automatically point the spotlight on them whenever energy prices shift significantly. The highest imperative of the organization is to control and manipulate the supply of oil, and as a result, its market price. In doing so, they maintain a sustainable level of production that rewards them with optimal returns for the quantity sold. The foundation of their monopolistic power rests on their share of total global oil reserves, which in 2015 was roughly 80 percent.[1]

Initially, when the price of oil plummeted from over $110bbl in June 2014, to under $50bbl in August of 2015[2], many media outlets focused their attention on OPEC as they ramped up supply in order to preserve a powerful market share. It was curious, at first, why they would defy the economic theory of monopoly power; had they decided to suddenly compete against *each other*? Surely not; simple game theory advocates that

[1] . OPEC (2016). *OPEC: OPEC Share of World Crude Oil Reserves*. [online] Available at: http://www.opec.org/opec_web/en/data_graphs/330.htm [Accessed 26 Sep. 2016].
[2] InfoMine. (2016). *5 Year Crude Oil Prices and Price Charts*. [online] InfoMine. Available at: http://www.infomine.com/investment/metal-prices/crude-oil/5-year/ [Accessed 26 Sep. 2016].

there is a compelling amount of incentive to sustain perfect cooperation in a market situation like this. The motivation to boost production came from the introduction of a new major player in the market – one whom in the past decade of exploration and development had harnessed the technology to feasibly access a greater volume of supply, enabling them to impact global energy prices… the United States of America.

Though they rank only 11th in proven oil reserves[3], the US steadily became the largest producer of petroleum and natural gas hydrocarbons by 2015[4]; the secret to their growth in production was newly developed technologies that allowed them to access challenging reservoirs of shale oil and gas. Originally deemed as overly-cumbersome and economically infeasible, the supply of hydrocarbons contained in these reservoirs, guarded by layers of shale formation, began being extracted by the controversial method of hydraulic fracturing ("hydrofracking", or "fracking") and horizontal drilling.

The use of these new technologies has shifted world energy markets, disrupting the historic market patterns of the global energy sector by gradually converting the US from a net importer of natural gas, to a prospective net exporter in the years since. These new methods accelerated the growth of the shale gas and oil industry in North America. Between 2002 and 2006, the US experienced a "boom"[5] in shale discoveries, including the Barnett formation located in Texas, and the Marcellus formation in Pennsylvania[6]. By

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[3] World Atlas. (2016). *The World's Largest Oil Reserves by Country*. [online] Available at: http://www.worldatlas.com/articles/the-world-s-largest-oil-reserves-by-country.html [Accessed 26 Sep. 2016].

[4] . EIA (2016). *United States remains largest producer of petroleum and natural gas hydrocarbons - Today in Energy - U.S. Energy Information Administration (EIA)*. [online] Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=26352 [Accessed 26 Sep. 2016].

[5] Economicshelp.org. (2012). *Economic Booms | Economics Help*. [online] Available at: http://www.economicshelp.org/blog/glossary/booms/ [Accessed 26 Sep. 2016].

[6] EurekAlert! (2016). *Unconventional natural gas reservoir in Pennsylvania poised to dramatically increase US Production*. [online] Available at: https://www.eurekalert.org/pub_releases/2008-01/ps-ung011708.php [Accessed 26 Sep. 2016].

2009, the US became the world's largest producer of natural gas, surpassing Russia[7]. This growth was largely triggered by the high natural gas prices during the 2000's[8].

In 2010, 76 percent of global unconventional gas output came from the US[9]. In 2013, the US Energy Information Administration (EIA) forecasted a 113 percent increase in US shale gas production by 2040 – which would result in a 50 percent share of total natural gas production, up from 34 percent[10]. Although the US is currently the most dominant producer of shale gas, a vast number of reservoirs are scattered throughout the continent of North America.

2.2 Canadian Shale Plays

Canada has been developing new and advanced methods of hydraulic fracturing and horizontal drilling for a few decades now. Through various means of testing, it has been estimated that there is potentially 1,000 Trillion cubic feet (Tcf) of natural gas in Canadian shale formations, with upside potential on this assessment[11]. In 2011, Natural Resource Canada estimated that Canadian gas usage will rise gradually, from roughly 2.9 Tcf per year in 2008 to 3.9 Tcf in 2020 through increasing industrial demand for power generation[12]. New discoveries in the shale formations of Canada could very well be the answer for this increase in demand.

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[7] EIA (2012). *The US surpassed Russia as world's leading producer of dry natural gas in 2009 and 2010*. [online] Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=5370
[8] Wang, Z. and Krupnick, A. (2015). A Retrospective Review of Shale Gas Development in the United States: What Led to the Boom? *Economics of Energy & Environmental Policy*, 4.
[9] Deloitte, (2013). *Shale Gas Supply Chain Opportunities in New Brunswick*., 57
[10] Munasib, A. and Rickman, D. (2015). *Regional economic impacts of the shale gas and tight oil boom: A synthetic control analysis*. Regional Science and Urban Economics, 1
[11] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 3

Though the west coast of Canada holds the largest share of this resource, its dispersion across the country is widespread. There are four major shale formations with great potential in BC. The Horn River Basin in Northern BC has been projected to hold 448 – 500 Tcf; 20 percent of which is deemed recoverable from the National Energy Board (NEB). The Montney shale/tight gas region in BC is showing to be a promising reservoir of natural gas; however, estimates vary widely from 80 to 700 Tcf of supply. Also on the radar in BC are the Liard basin and the Cordova embayment to the east. In southern Alberta and Saskatchewan, there is an estimated 100 Tcf of natural gas that can be recovered from the Colorado Group. Ontario contains 3 shale plays with potential for recoverable natural gas: the Antrim/Kettle Point formation, which is a fraction of the famous Marcellus shale play (located in the states of Pennsylvania, Ohio, New York, and West Virginia), and the Blue Mountain formation[12]. Quebec holds basins containing Utica shale, which can be found in Questerre's territory and others. Finally, New Brunswick and Nova Scotia both have an estimated 67 Tcf and 69Tcf of natural gas respectively within their shale formations[12]. Needless to say, Canada is proving to have an abundant supply.

2.3 Hydraulic Fracturing

Shale gas and shale oil are formed through a similar process as regular carboniferous products. Organic matter and sediment are deposited into lakes, and over millions of years they are continually buried under layers and compressed with pressure over time. In the case of shale gas, the organic matter was buried in shale deposits. Shale is an unconventional gas reserve because the gas is not concentrated in a shallow reservoir underground, it is dispersed within layers of shale that have unusually low permeability[12]. The pore spaces in shale, through which the natural gas must flow out of, are 1000 times smaller than pores in normal sandstone reservoirs. The gaps that connect pores are only roughly 20 times larger than a single methane molecule[13]. Because shale layer exteriors have an extremely low degree of permeability, they require substantial technological rigor to extract the gas inside them.

Fracturing shale formations in order to overcome the low permeability of its exterior is a technique that has been used since the late 1800's[14]. In its earliest days, this process was mainly carried out by drilling a well vertically, followed by setting off explosives where it connects to the shale formation. In the 1940's, hydraulic fracturing that bears a resemblance to more of a modern-day procedure was developed. A steel pipe would be inserted into the shale rock, then through the pipe, a high volume of pressurized water would be pumped straight into the formation. The pipe would be perforated using explosives and the excess pressure would force the rock to crack, thereby freeing up the supply of gas and allowing it flow to a well to be extracted[15].

Beginning in the early/mid-2000's, through the combination and refinement of both hydraulic fracturing and horizontal drilling, a more efficient and profitable process was designed. Through the combination of both processes:

"Well bores are drilled vertically to the gas bearing formation and then the drill bit is turned so that the bore extends horizontally along the formation, for a mile or more. In this manner, the well bore is able to intersect with a substantially greater area of the geology and can intersect perpendicularly to naturally occurring fractures. The horizontal well bore is then punctured by a series of small explosive charges, which create openings into the shale layer emanating from the well bore. Water, along with lubricants, biocides,

[12] Government of New Brunswick. (2014). *Exploring Natural Gas in New Brunswick*, 2
[13] National Energy Board. (2009). *A Primer for Understanding Canadian Shale Gas*, 5
[14] Park, A. (2012). *Shale Gas in New Brunswick : Promise, Threat, or Opportunity*. Journal of New Brunswick Studies.

and small particulates such as sand, is injected at high pressure into the well bore where the pressure of the water fractures the formation along naturally occurring fracture points or seams. The particulates help to hold the fractured layers apart, enabling the gas trapped within the geology to be released into the well bore, where it flows to the surface, along with hydraulic fracturing fluids initially injected into the well."[15]

The horizontal drilling process poses the risk of the borehole collapsing (which has been reported in Alberta in Saskatchewan), making the inspection and engagement of it a lengthier, riskier, and precarious endeavor[16].

2.4 Natural Gas in New Brunswick

In New Brunswick, 50 oil and gas wells have been hydraulically fractured since 1990, 30 of which are for natural gas. The mining of oil shale and hard bitumen began in the early 1850's around the Albert Mines in Albert County. In the 1860's, the first long-term producing oil and gas field was discovered at Stoney Creek, south of Moncton. Its production period ran from 1910 to 1991, and again resumed in 2006, when new advances in extraction techniques were adapted and the price of gas rallied to an attractive and profitable level for extractors[17]. More recently, the discovery of the McCully gas field near Sussex in 2003 sparked additional production within the province[22]. The carboniferous oil shale is located at the surface around Hillsborough, Albert Mines, Rosevale in Albert County; around Sussex and Norton in Kings County; and around Dover and Saint-Joseph in Westmorland County. It lies in the subsurface as deep as 3-4 kilometers, from Sackville and Moncton, and Sussex and Norton[22]. Currently,

[15] Brasier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 7
[16] National Energy Board. (2009). *A Primer for Understanding Canadian Shale Gas*, 6

[17] Park, A. (2012). *Shale Gas in New Brunswick : Promise, Threat, or Opportunity.* Journal of New Brunswick Studies.

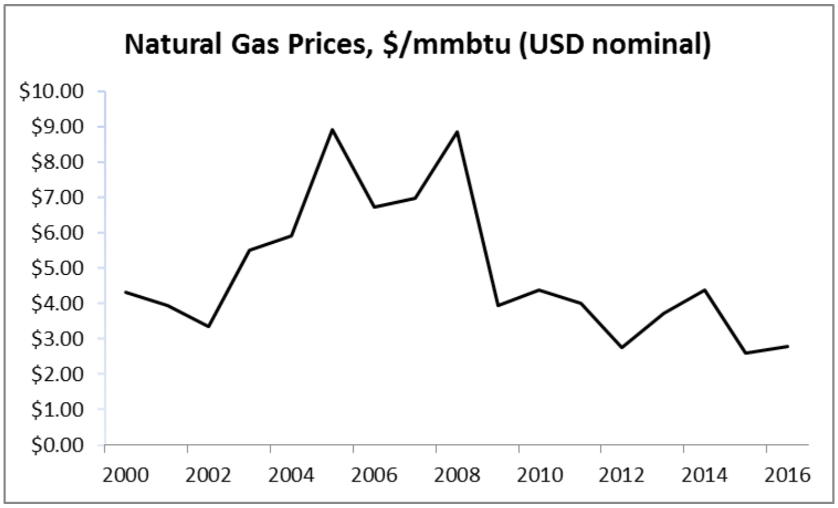
Corridor Resources Inc. is established in New Brunswick and Nova Scotia as a major player in the exploration and development of gas in Atlantic Canada[18].

In general, estimates of the supply of natural gas within New Brunswick shale formations amount to roughly 69 Tcf; which according to the previous Minister of Energy, would be enough to heat every home in the province for 630 years, or serve the province's power needs for the next 100[19]. At this point, estimates of New Brunswick's potential natural gas industry through hydraulic fracturing are still tentative; however, it is popularly regarded as one of the province's top resource prospects and currently under review by the provincial government. The exactitude of supply estimates are expected to sharpen each year, as numerous impact assessments that are currently underway will help to identify which locations promise wealth to the province and exhibit adequate environmental safety. Eventually, through a multitude of deliberate research efforts, the province should be able to reasonably confirm the total supply and environmental risk, which will allow for a more credible policy analysis.

New Brunswick's research and exploration into shale gas has still not fully matured due to limited resources, and a moratorium that was placed on hydraulic fracturing in 2014. Up until 2014, 30 natural gas wells had been constructed and were in production[20]. Although a Deloitte study (2013) qualified New Brunswick's current industries to be somewhat ready to adopt the fracking industry, the decline in the price of natural gas over the past 8 years has diluted the relevance of its potential industrial impact. The drop in prices has reduced the economic profitability of extraction, and consequently deferred major investments until the opportunity to profit resurfaces.

[18] New Brunswick Commission on Hydraulic Fracturing. (2016). *The Findings*, 18
[19] The Globe and Mail (2012). *N.B. shale gas could power province for a century: minister.*
[20] Deloitte, (2013). *Shale Gas Supply Chain Opportunities in New Brunswick*., 9

Figure 1:
Natural Gas Prices



Source: *Global Economic Monitor (GEM) Commodities*, The World Bank (2016)

While investment is deferred from natural gas exploration, New Brunswick must confront another future obstacle; the decline in offshore natural gas extraction in Nova Scotia[21]. A report conducted by Jupia Consulting for the Atlantic Centre for Energy (2014) estimates that the demand for natural gas in the Maritimes could exceed the domestic supply as soon as winter of 2017[22]. Natural gas use increased by roughly 200 percent in New Brunswick between 2005 and 2013, it rose by over 300 percent in Nova Scotia in the same period[23]. If the current trend in production levels were to continue without further drilling, the region's gas production could come to a complete halt as soon as 2020[24]; this would put upward pressure on prices, causing an increase in the cost of living for east-coast residents.

[21] New Brunswick Commission on Hydraulic Fracturing. (2016). *The Findings*, 14
[22] New Brunswick Commission on Hydraulic Fracturing. (2016). *The Findings*, 14
[23] Atlantica Centre for Energy. (2015). *Natural gas supply and demand report. New Brunswick and Nova Scotia 2015 – 2025*, 2

New Brunswick's current natural gas market is threatened by current market conditions, brought on by economic realities. These free market realities, however, are not the only constraint on this industry. The provincial government has intervened by placing a moratorium on hydraulic fracturing, a major platform of Liberal Party that was imposed shortly thereafter their victory over the Tories during the provincial election of 2014. The Liberals – and many environmentalists – raised concerns over the risks that the chemicals used in the fracking process entail for safety of local freshwater sources. The moratorium cannot be renegotiated until 5 conditions are met:

1) A "social license" is to be established through consultations to lift the moratorium;
2) Clear and credible information on the impacts on air, health and water so a regulatory region can be developed;
3) A plan to mitigate impacts on public infrastructure and address issues such as wastewater disposal is established;
4) A process is in place to fulfill the province's obligation to consult with First Nations;
5) A "proper royalty structure" is established to ensure benefits are maximized for New Brunswickers.[24]

The moratorium was extended indefinitely in 2016, and progress towards meeting these conditions is still underway. Supporters of the moratorium cite that its benefits extend beyond ensuring the security and health of local water systems. David Coon, the leader of the Green Party of New Brunswick has stated that "by the time natural gas

[24] CBC News. (2014). *Shale gas moratorium details unveiled by Brian Gallant*

prices start to come back in any significant way, we'll be well down the road to building an economy based on greener energy."[25] While this may be true, in a latter section we will discuss the arguments for and against this proposition.

The indefinite moratorium on hydraulic fracturing came at a rocky time for the province. New Brunswick has never been in contention for the title of 'economic powerhouse' in Canada. But in recent years, its fiscal and market conditions have been in evident decline, and the headline of much criticism and speculation.

3. Provincial Economy and Policy

3.1 Economic Review of New Brunswick

New Brunswick is home to a near-even mix of urban and rural habitants; geographically, however, its land is dominated by forests, which occupy roughly 90 percent of its total surface area[26]. The land is rich with merchantable resources that support a high-volume trade partnership with the US; resources include: hardwood and softwood lumber, coal, zinc, silver, copper, bismuth, cadmium, gold, antimony, potash, oil, and natural gas[27]. It is also home to one of the most lucrative fishing industries in North America, solidifying its position as an integral source of supply with the proven capacity to support the insatiable worldwide demand for salmon, herring, sardines, oysters, clams, and lobsters[27]. It is the home to two of the largest and most successful companies in Canada: the Irving group, which operates the largest oil refinery in Canada and leads the province in its forest industry, and McCain Foods, which sells its frozen

[25] CBC News. (2016). *Supporters, opponents doubt fracking will come to N.B. after report.*
[26] The Columbia Encyclopedia. (2016). *New Brunswick (province, Canada).* 6th ed.

food products on an international scale[27]. The two companies have optimized production along the supply chain through the process of vertical integration and are considered to be the largest employers in the province, along with the government of New Brunswick.

New Brunswick exported a cumulative $12 billion in 2015, over 90 percent of which was shipped to the US[28]. Its exports are driven in large from the product of its vast resources and its manufacturing sector. The table below displays the top exporting industries in 2015 - as classified under the North American Industry Classification System.

Table 1:
Top Exporting Industries, New Brunswick, 2015

000's of Dollars, CAD	2015
32411 - Petroleum Refineries	6,744,231
31171 - Seafood Product Preparation and Packaging	1,070,635
32211 - Pulp Mills	541,393
32111 - Sawmills and Wood Preservation	440,697
32212 - Paper Mills	411,876
21111 - Oil and Gas Extraction	396,043
21239 - Other Non-Metallic Mineral Mining and Quarrying	306,538
31141 - Frozen Food Manufacturing	244,371
11251 - Animal Aquaculture	207,126
11411 - Fishing	167,833

Source: Trade Data Online, Government of Canada. Accessed on 09/24/2016

[27] Forbes, E. (2001). *New Brunswick*. [online] The Canadian Encyclopedia. Available at: http://www.thecanadianencyclopedia.ca/en/article/new-brunswick/ [Accessed 26 Sep. 2016].
[28] Government of Canada, Trade Data Online. (2016). *Canadian Total Exports, Listing of Top 25 Industries (5-digit NAICS codes), New Brunswick*.

Trade is facilitated in New Brunswick through Port Saint John, the focal point of all shipments going in and out of the province. Port Saint John is located in the city of Saint John, and is praised for its ability to resist freezing over during the months of winter. It is situated at the merging point of the Saint John River and the Atlantic Ocean, and is impervious to freezing in sub-zero temperatures due to its great depth. It permits the transport of 28 million tons (on average) of diverse cargo annually[29].

Even though New Brunswick has been able to identify its economic strengths, it frequently lags behind other provinces in measurements of economic wellbeing. Table compares a few of New Brunswick's key economic indicators to the national average:

Table 2:
Comparison of NB to Canada, 2014 – 2015

Statistical Summary - Growth Rates[1] (as of January 22, 2016)		
	2014 to 2015	
	N.B.	Canada
Population and Labour		
Total Population (July 1)	-0.1	0.9
Labour Force	-0.7	0.8
Employment	-0.6	0.8
Unemployment Rate (%)	9.8	6.9
Participation Rate (%)	62.7	65.8
Wages and Salaries[2]	2.5	2.6
Consumers and Housing		
Retail Trade[2]	3.2	2.1
Consumer Price Index	0.5	1.1
Housing Starts	-12.3	3.3
Business		
Manufacturing Sales[2]	-9.8	-1.6
International Exports[2]	-6.3	-2.7
Building Permits[2]	-3.0	-0.1

[1] Per cent change unless otherwise indicated.
[2] Year-to-date (unadjusted for seasonality).
Source: Statistics Canada.

[29] Government of New Brunswick. (2016). *$136 million invested in Port Saint John*. News Release.

Source: Economic Outlook 2016-2017, Department of Finance, Government of New Brunswick

In its Economic Outlook for 2016, the Government of New Brunswick cited a number possible market conditions that are constraining the provincial economy. The headlining issues were the growing demographic (aging) realities, the impact of low global growth on exports, lack of private investment, fiscal measures, and the recently announced suspension of operations at the Picadilly mine[30].

Although a growing number of Canadian regions are forecasting declines in their population, New Brunswick's projections are among the bleakest in the country. Roughly 21,000 citizens have left the province since 2005; and in 2014, for the first time in its history, it recorded more deaths than births in the province[31]. It is known for having one of the highest unemployment rates in Canada; as well as an aging population, conflict over divisive language barriers, and a significant portion of habitants residing in rural areas.

With almost half of its population living in rural areas, resources for services such as health care and education must stretch to great lengths in order to accommodate people from all areas. This foregoes the province's opportunity to invest in centralized public infrastructure that would allow for the economies of scale. The fact that it is a bilingual province is perpetually argued to be a drag on the economy through limiting employment opportunities because of language barriers.

"71 per cent of French New Brunswickers are bilingual, while only about 15 per cent of the province's English can speak French. 'More than 70 per cent of the province is disqualified from a majority of government positions, and a growing number of private

[30] Department of Finance, Government of New Brunswick. (2016). *2016 – 2017 Economic Outlook*, 7
[31] Patriquin, M. (2016). *Can anything save New Brunswick?* MacLean's Magazine.

sector positions,' says Sharon Buchanan, the president of the Anglophone Rights Association of New Brunswick."[32].

Provincial debt has been steadily rising over recent years; in the 2014-2015 fiscal year provincial debt reached roughly $12.2 billion, or 37.7 percent of nominal GDP[32]. Between 2009 and 2013, New Brunswick's net debt increased by 45 percent[33]. Until recently, the province had a reliable share of federal equalization payments; however, due to the weakening economic performance of Ontario and other areas, the volume of payments it usually receives has dissipated and been redistributed to other provinces as their fiscal stability declines[34].

Government expenditures have consistently exceeded its total revenue year after year, and have resulted in the implementation of austere tax, such as raising the provincial sales tax and the corporate income tax (for large companies)[34]. Subsequently, it seems unlikely that the province could further raise additional revenue through these types of policy changes without compromising economic growth and the tax competitiveness of New Brunswick[35].

As an example of the dampening business activity in the province, PotashCorp of Saskatchewan suspended their operations at the Picadilly Mine in New Brunswick in January, 2016. The suspension of potash production at this site resulted in the layoff of 420-430 workers. The site will be maintained indefinitely through annual investments of roughly $15 million[36] until global market conditions in the potash industry shape up. The

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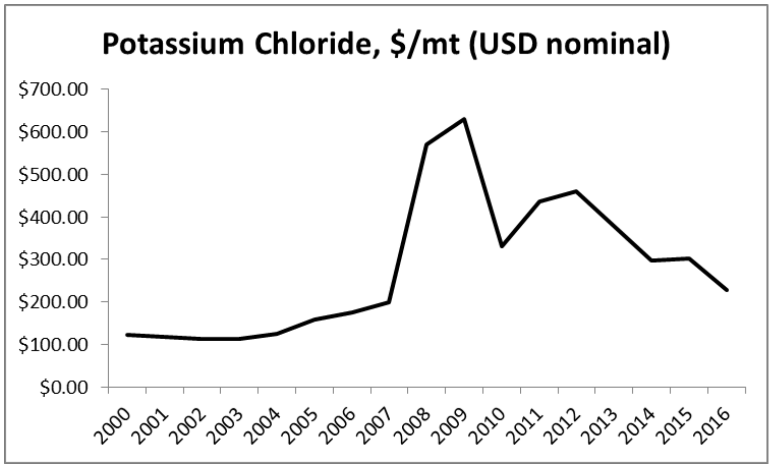
[32] Murrell D., Fantauzzo, S. (2014). *New Brunswick's Debt and Deficit: A Historical Look*, 6.
[33] Murrell D., Fantauzzo, S. (2014). *New Brunswick's Debt and Deficit: A Historical Look*, 7.
[34] CBC News. (2016). *Brian Gallant's government endures 2 years of money struggles.*
[35] Murrell D., Fantauzzo, S. (2014). *New Brunswick's Debt and Deficit: A Historical Look*, 11.
[36] CBC News. (2016). *PotashCorp suspends Picadilly mine in N.B., cuts 430 jobs.*

closure came as a big disappointment to the province, but little surprise to the public; given weakening commodity prices from sluggish global growth.

Figure 2:
Market Price of Potash, 2000 – 2016



Source: Global Economic Monitor (GEM) Commodities, The World Bank (2016)

PotashCorp is the world's largest fertilizer company. They had invested $2 billion - to date - on the Picadilly operation[37]. Another potentially influential factor in its decision to cease operations was the moratorium placed on fracking, as they had been operating with access to the natural gas that was being fracked close by. Having a direct source of energy only kilometers away was likely a valuable resource for the mining operation at Picadilly. Upon the implementation of the moratorium on fracking, the general manager of PotashCorp New Brunswick said the company "would have to

[37] The Globe and Mail. (2016). *PotashCorp closes N.B. mine as prices plummet, stock falls.*

consider its options.”.[38] The moratorium quite likely amplified the other economic conditions that led to the shutdown.

Other industries, like electricity providers, rely heavily on the availability and price of fuel sources. NB Power is New Brunswick’s supplier of electricity. Its generating stations are located at various locations in the province and they make use of a variety of energy sources to produce electricity. As of 2013, they operate 13 generating stations by using energy mostly from heavy fuel oil, coal, water, uranium, and diesel.[39] They operate the only active nuclear generating plant outside of Ontario at the Point Lepreau Nuclear Generating Station, which recently spent a number of years being refurbished (with an estimated total cost of $2 billion)[40]. There are seven hydroelectric dams in the province, the most noteworthy being the Mactaquac generating station, located just upstream of the capital city, Fredericton. And finally, there are two thermal and three combustion turbine facilities – which cumulatively account for over half of the electricity generation in the province.[41]Although NB Power has not been affected by shale gas exploration, in latter sections of this paper, we will discuss why its relationship may be significant.

3.2 Environmental Concerns

The root of all controversy over shale gas exploration is its effect on the environment. Certain jurisdictions have already banned the practice, citing a vast amount of environmental concerns. Quebec’s government, most notably, put a permanent ban in

[38] CBC News. (2014). *Shale gas moratorium details unveiled by Brian Gallant.*
[39] NB Power. (2016). *System Map*. [online] Available at: http://www.nbpower.com/en/about-us/learning/system-map [Accessed 26 Sep. 2016].
[40] CBC News. (2013). *Point Lepreau costs could hit $3.3B, PMO memo says*
[41] NB Power. (2016). *Divisions*. [online] Available at: http://www.nbpower.com/en/about-us/divisions [Accessed 26 Sep. 2016].

place after an environmental analysis revealed a number of imminent risks to the local environment. As of March 2011, no fracking can be authorized in the province, unless it's part of a scientific investigation.[42] As mentioned earlier, New Brunswick has also banned hydraulic fracturing; however, the length of the ban is dependent on the completion of the 5 obligations in the stated criteria.

To date, the activities in fracking that are known to have negative consequences on the environment are: the consumptive use of freshwater, disposal of wastewater, leaks causing contamination to groundwater supplies, and society's forward-looking ambition to shift away from energy sources that emit greenhouse gases (GHG).

Fracking requires a large amount of water in order to attain pressures that fracture the pores of shale rocks. The ability to recycle this water depends on the geological surroundings of the drilling location. It has been estimated that the share of water that returns to the surface is in between 15 – 80 percent, a rather unpredictable range[43]. The unpredictability of the amount of water that can be recycled during the process of fracking would indicate that it is a consumptive process in nature[44]; which further complicates its path to a non-disruptive relationship with the environment. It has been pointed out that the levels of hydraulic fracturing carried out in Canada up to the present day require 17 times less water than industries like pulp and paper manufacturing[44]. However, the shale industry in Canada is still relatively new, with technology advancements that would likely be considered to be in its premature stage of development compared to what would come if it were expanded to its full potential.[45]

[42] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 4
[43] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 6
[44] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 7

The water that is used in the process of fracking must also be combined with various additives in order to maximize its effectiveness. Added to the water are chemicals that increase the flow rate of the molecules, biocides that prevent organisms from growing in the well, and scale inhibitors[45]. The wastewater that is returned to the well typically picks up salt from certain layers of the sub-surface terrain. In some cases, there has been wastewater that resurfaces, containing radioactive elements.[46] In most cases, the water that flows back is not suitable to be treated and returned to drinking water sources; it can be injected into deep disposal wells, or treated and reused for further fracking, quantities vary by location[46].

In some cases, the wastewater can be treated in order to replenish local sources of drinking water from rivers and lakes. However, as mentioned above, some wastewater that returns to the surface may be contaminated with radioactive elements; which, in small traces, may go undetected - and returned to drinking water sources where local water-treatment plants are not properly equipped to manage radioactivity.[47]

Another concern with fracking is the possibility of direct leakages, from drill sites into groundwater supplies. Local residents who depend on groundwater to supply their wells have stressed their concerns over the risk fracking to leak chemical fluids, or the gas itself into their water wells.[47] This event can occur if the wellbore, drilling holes, or flow pipes are not properly sealed or able to resist cracking or being fractured. There have been numerous reports of this from Pennsylvania residents. Spills from fracking

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[45] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 8
[46] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 10

fluid, wastewater, and hydrochloric acid have been leaked due to faulty equipment used to seal off the drill site.[47]

New Brunswick's former Conservative government introduced new measures in 2013 aimed at ensuring the protection of local water supplies, improving water management, and committing more resources to environmental monitoring.[48] However, these policies were not enough to tame the growing concerns of New Brunswickers.

With the rising global initiatives to significantly reduce GHG emissions in the fight against global warming, many skeptics of shale gas exploration argue that it is counterproductive to further invest in developing new technologies in this industry when the majority of the world's nations are funding the innovation of renewable (green) energy sources.

Innovation into new and greener energy sources is swiftly gaining momentum around the world, most notably through efforts toward solar and wind generation, and biofuels. However, the cost-effectiveness of each of these methods has yet to reach a level that can accommodate the masses of energy consumers worldwide[49]. With this in consideration, many argue that switching to natural gas as a source of energy and power generation is the biggest step in the right direction that can be taken, given current costs.

Methane, which is the largest component of natural gas, is 21 times more potent as a GHG than carbon dioxide, the most common GHG, if released into the atmosphere.

[47] Oza, M. (2011). *Shale Gas in Canada : An Overview*, 9
[48] Department of Energy and Mines, Government of New Brunswick. (2014). *The New Brunswick Oil and Natural Gas Blueprint.* 5.
[49] World Energy Council. (2016). *The world is far away from achieving environmentally sustainable energy systems*. [online] Available at: https://www.worldenergy.org/news-and-media/press-releases/the-world-is-far-away-from-achieving-environmentally-sustainable-energy-systems/ [Accessed 26 Sep. 2016].

But if properly captured and burned, methane produces only half of the GHG emissions of coal, which is why it is considered cleaner than other fossil fuels.[50]

As of 2013, New Brunswick's 13 generating stations reached a capacity of 3,1513MW, with 889MW being produced by hydroelectric generation (highly environmentally friendly).[51] However, the remaining sources of power generation in the province come mainly from nuclear and thermal generation (thermal implies either the use of coal, or other fuel such fracked natural gas).

Coal powered plants are known to be the worst for the environment. Due to its chemical makeup, coal emits the most GHG into the atmosphere, and it is the least efficient in the process of electricity generation, approximately a third of the energy produced from burning coal is effective in the generating process.[52]

On the other hand, nuclear generation is revered for its efficiency in generating power, it is estimated that roughly 99 percent of the energy from nuclear reactions is effectively used in power generation.[53] Though there are clear benefits to its efficiency, and it is a technique that is used widely around the world, there is a great amount of potential danger associated with nuclear plants. If the facility was ever structurally compromised and radioactive elements were leaked into the air of nearby regions, the consequences to the surrounding area would be life-threatening. Given their potential to cause environmental catastrophes, these facilities are extremely costly to build and

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[50] New Brunswick Commission on Hydraulic Fracturing. (2016). *Potential Economic, Health and Environmental Impacts of Shale Gas Development.* 29

[51] NB Power. (2016). *Divisions*. [online] Available at: http://www.nbpower.com/en/about-us/divisions [Accessed 26 Sep. 2016].

[52] NB Power. (2016). *Thermal*. [online] Available at: https://www.nbpower.com/en/about-us/learning/learn-about-electricity/thermal/ [Accessed 26 Sep. 2016].

[53] NB Power. (2016). *Nuclear*. [online] Available at: https://www.nbpower.com/en/about-us/learning/learn-about-electricity/thermal/ [Accessed 26 Sep. 2016].

maintain, as New Brunswick has experienced already. The world has already witnessed nuclear disasters at plants in Chernobyl, Three Mile Island, and Fukushima.[54]

Using natural gas as a primary source of power generation is growing popular among discussion in North America. It is a greener alternative to coal power, and a much less expensive (and risky) alternative to nuclear plants. The risk of relying on it as a primary source of power generation is mostly attributed to the price volatility of the market it is traded in, and the impact that a spike in prices would have on local power plants.[54]

4.0 Review of Previous Methods and Findings

Public opinion on the matter varies widely; very little middle ground has been made between both ends of the spectrum. While there are a few details that both sides can agree on, there are firm discrepancies that remain on certain items in the mix. The only way to truly evaluate the issues entangled in these policies is through resilient and ongoing research into the matter. This section will review previous studies on the impact of shale gas exploration, with the intent of comparing and contrasting their methodologies and findings to the ones in this study.

Cost-benefits analyses are not considered in this section, as this study makes no effort to quantify the negative externalities that are generated in the process of shale gas exploration.

[54] Breaking Energy. (2012). *Coal, Nuclear and Natural Gas: What Will Keep The Lights On?* [online]. Available at: http://breakingenergy.com/2012/03/06/coal-nuclear-and-natural-gas-what-will-keep-the-lights-on/

4.1 The IMPLAN Model

Using the Marcellus Shale formation in western and northern Pennsylvania, Considine et al. (2009) estimate the impact of the shale gas extraction using the IMPLAN input-output model. This model has been used by governments, researchers and consultants to assess the impact of various policies[55]. The data that was inputted into the model was acquired by gathering detailed expense accounts from the shale gas industry, which was gathered through a survey administered to various firms in the industry. The survey was given to 36 firms, however, only 7 of which responded. Using the data from the responding firms, spending estimates were extrapolated for the entire industry. It is important to note that industry expenses per company are very confidential pieces of data. Although only 7 responded, these firms accounted for 59 percent of total drilling in Pennsylvania[56]. This is a mitigating factor, and

The results of their study suggested that in 2008, shale gas extraction generated $2.263 billion in economic activity, created 29,284 jobs, and paid $238.5 million to state and local tax authorities in Pennsylvania[56].

Although the IMPLAN model is a commonly used tool in the US, its capacity to evaluate the impact of spending in the amount of billions of dollars is limited. In magnitudes like these, the direct spending likely stretches the true relationships of variables within the model[56].

Two criticisms of this study will be addressed for this paper. The first is that it is assumed that all of the royalty and leasing payments to private households are spent by

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[55] Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1244

[56] Considine, T., Watson, R., Entler, R., Sparks, J. (2009). *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play.* [online]. Available at: http:// groundwork.iogcc.org/sites/default/files/EconomicImpactsofDevelopingMarcellus.pdf

households on good and services produced in Pennsylvania in the same year that those payments were received. This is extremely important, considering that these payments accounted for 68.6 percent of all direct industry spending in 2008[57]. This utterly ignores any consideration to the behavior of household spending, and propensity to save.

Secondly, there is a lack of robust information presented to support the claim that 95 percent of all industry expenditures are confined to the state of Pennsylvania. Research has shown that although the study was able to track down the geographical location of suppliers to the industry, it failed to conclude whether the supplier was incorporated within the state, of if it was just one branch operating outside of the state that it is headquartered in[58]. This would fail to capture leakages in the supply chain, whereby suppliers actually import their capital from out-of-state, which transfers wealth away from the state.

IMPLAN models used for economic impact analyses fail to account for the possibility of the "crowding out effect" of other users of the resource; for example, hotels and restaurants that are already operating at full capacity serving workers from the gas industry are now no longer available for tourists and other households[58].

Another weakness of the IMPLAN (and most input-output models) is its tendency to overstate the direct spending of each industry that is affected in the model, if more than one industry is used simultaneously. Because every industry is supported through a supply chain of other industries, the impact of its output is partially attributed to its suppliers. An economist would have a hard time using this type of model for more than

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57 Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1245

58 Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1246

one impact assessment at a time as there is the great potential for double counting the spending from each industry involved[59].

4.2 Difference and Difference

A large number of studies to-date on the economic impact of shale gas exploration have used the IMPLAN model. But instead of using this type of model, Murray and Ooms (2008) compares historical data on certain indicators such as population, incomes, and employment over different time periods across counties in four regions (one in Texas, two in Arkansas, one in Pennsylvania) of the country[60].

The authors divided data over a 16 year period into two sections, one from 1990 – 2000, and from 2000 – 2006. During the first period, none of the regions had yet begun to extract natural gas by using hydraulic fracturing. In the latter period, three of the four regions (all except Pennsylvania, which began in 2006) were active in shale gas extraction. This allowed them to conduct a regional analysis, where drilling activity was compared across different time periods in the same regions; and also a cross-county analysis, where counties with different levels of annual production were compared across the same time period. A side-by-side comparison of the growth rates of the selected economic variables were used to calculate a crude estimate of the economic impact of shale gas exploration[61].

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[59] Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1247

[60] Murray, S., Ooms, T. (2008). *The Economic Impact of Marcellus Shale in Northeastern Pennsylvania by Joint Urban Studies Center*. [online]. Available at: http://www.institutepa.org/marcellus/ mtwhitepaper.pdf

[61] Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1246

The authors conclude from their findings that the changes in economic indicators in shale areas were significant, and in non-shale areas, "negligible"[62]. The annual rate of population growth did not significantly change in the county in Texas (0%). In Arkansas there were decreases from the first period to the latter (1.5% and 0.9%). Pennsylvania, which did not engage in shale gas drilling, experienced a decline of 1.3%. "If we assume that no other economic or demographic variables affected Pennsylvania any differently than these other areas, then we can estimate that shale gas drilling increased the annual population growth rate by between 1.3% and negative 0.2%" Kinnaman (2011)[63].

Kinnaman (2011) reviewed the study of Murray and Ooms (2008), and pointed out in their review that by their estimates, shale drilling and extraction activities actually *decreased* per-capita incomes by between 0.8 and 3.1 percent. They also imply that, as mentioned earlier, micro data on the use of out-of-state capital is an aspect that should not be neglected when assessing the impact of gas drilling. Kinnaman (2011) concludes that their report adds very little to the understanding of shale gas' impact on economies, citing that Pennsylvania is a poor control area to use in comparison to Texas and Arkansas because "regional economic and demographic forces are likely to affect the Pennsylvania economy and the Texas and Arkansas economies in separate ways"[63] Kinnaman (2011).

4.3 General Findings at Local Economies

Positive spillovers into the local economy generally fall in line with what most researchers would expect; increases in the demand and purchase of intermediate goods, induced local spending, etc. But at the same time, there is also the potential for negative

[62] Kinnaman, T.C. (2011). *The economic impact of shale gas extraction: A review of existing studies.* Journal of Ecological Economics. 1247

effects, such as rising local factor and goods prices, and adverse effects on the community's quality of life[63].

Gopalakrishan and Klaiber (2014) find that within a proximity to shale exploration sites in Washington County and Pennsylvania, there were observable negative effects on property values from 2008 to 2010.[64] Other studies can confirm this trend; Throupe et al. (2013) found that there was a reduction in bid values for homes located near "fracking" sites using contingent valuation surveys in Florida and Texas.[65]

Brasier et al. (2014) conducted a study that focused on four counties situated on the reservoirs of the Marcellus Shale formation. They focused on changes in indicators related to population, housing, local economics, crime, health, and healthcare access, K-12 education, agriculture and local governments as development in shale gas extraction proceeded in their local community.[66] Their analysis was unable to isolate a causal relationship; but, their assessment captures significant changes associated with shale gas exploration over time. Their estimates, coupled with the increase in shale gas development in Pennsylvania, are consistent with the general findings of what social scientists refer to as a "boomtown" development.[67] The term "boomtown" refers to local areas that experience a sudden onset of rapid growth in economic activity as a consequence of a new development – in this case, natural resource development.

These implications of these studies vary, and they are subjective to the respective state regions to which they are confined to. For example, regardless of the local region

[63] Munasib, A., Rickman, D. (2014). *Regional Economic Impacts of the Shale Gas and Tight Oil Boom: A Synthetic Control Analysis,* 1.
[64] Gopalakrishan, S. Klaiber, H. (2014). *Is the Shale Boom a Bust for Nearby Residents? Evidence from Housing Values in Pennsylvania.*
[65] Throupe et al. 2013 Throupe et al. (2013). *A Review of Hydro « Fracking » and its Potential Effects on Real Estate.* Journal of Real Estate Literature. Volume 21.
[66] Basier et al. (2014). *The Economics of Shale Gas Development,* 1
[67] Basier et al. (2014). *The Economics of Shale Gas Development*, 8

that boomtowns appear in, the sudden increases in population can place strains on social and healthcare services, law enforcement, and schools. But these consequences are mitigated to different degrees depending on the jurisdiction. In Canada, all resources under the ground are owned by the provincial government, therefore, the strain on these public/social services could be offset by the royalty structure paid to the Crown by extraction companies. Conversely, in the US, the private owner of the land owns the right to resources; therefore they cannot *directly* contribute to the local governments to offset the financial strain that is placed on them as a result of rapid population growth. Brasier et al. (2014) find that there is an initial strain placed on public services in order to keep up with the sudden boom in population, and increased competition in the housing market causing a lack of availability for local residents.[68]

From the reports that were gathered, they it is found that long-term residents note a change in the "social fabric" of their communities, due to the influx of newcomers. This is in line with prior studies on the relationship between boomtown developments and increased social problems, such as drug and alcohol abuse, domestic violence, rising divorce rates and mental health issues.[69] Just as is the case with the boom from newcomers, there are large impacts from the "bust" – the depletion of the resource and abandonment of the site.[70]

Within the housing market of these boomtowns there are winners and losers, depending on whether they own property or not. Some participants in the Brasier's et al.

[68] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 8
[69] Camasso, M. Kenneth, P. (1990). *Severe Child Maltreatment in Ecological Perspective: The Case of the Western Energy Boom"*. Journal of Social Service Research.
England, J. L. (1984). *Boomtowns and Social Disruptions.* Rural Sociology 49(2).
[70] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 8

(2014) study saw the boom as an opportunity to benefit from cheaper natural gas prices by converting the heat source their homes to natural gas. Others cashed in by raising the prices of their property, or purchasing housing units in advance of the boom. They found that some property owners downsized their buildings into separate apartment spaces or office space which they put up for lease, and were able to sell without much effort due to the steady increase in demand.[71]

On the flipside, those who did not own property – but relied on lease agreements for shelter - experienced negative consequences. As workers initially began to arrive in the Marcellus communities, they occupied temporary housing units such as hotels, campgrounds, or rental housing. Once a headquarters was established and confirmation was reached on the supply of resource in the ground, more workers were called to the site. For the long-term residents who depended on low rental fees, this was problematic. Rental companies inevitably increased the cost of rent (due to increased demand) once the term of the original leasing agreement expired.[72] Eventually, low income families began to struggle with the affordability of housing/rental prices and found themselves converting more of their disposable income into housing payments. This was found to be especially the case in rural areas, where there were relatively less housing options prior to shale exploration than in urban areas.[73]

In such cases, one might wonder why property owners/investors don't simply construct new homes to accommodate the influx of new workers. Resources in the

[71] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 32
[72] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 10
[73] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 10

ground, by nature, are non-renewable and fixed in supply. The supply of the available resource differs by region, and in some cases can be depleted in a matter of years. Therefore, if the expected lifespan of a project is only a few years, land developers and home builders typically exercise a reasonable amount prudent risk-aversion toward their capital to avoid investing in assets whose use will be short-lived and value reduced to nothing.

Aside from the local housing market, businesses in the region can adapt by shifting their services and products to better suit the booming industry and its workforce. Owners of businesses may convert their energy sources from coal/oil to natural gas in order to capitalize on direct access to the resource with little to no transportation margins applied to its delivery.[74] It has been reported that communities as a whole have built new electric power plants that are fueled with natural gas in order to benefit all local residents.[75]

All in all, it is generally found that local public policy needs to be adjusted to the specific needs of each individual county.[76]

5 Theory and Methodology

5.1 Resource Rent

[74] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 34
[75] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 39
[76] Basier et al. (2014). *The Marcellus Shale Impacts Study : Chronicling Social and Economic Change in North Central and Southwest Pennsylvania.* Center for Fural Pennsylvania, 58

An element in the determination of the cost and benefits of shale gas exploration is the instrument of resource rent; specifically in the context of measuring it as a factor of input to production. Companies that wish to extract shale gas from the ground are similar to other firms, in that they seek to maximize profits by hiring the optimal combination of labour and capital as inputs to production. Where they differ is in the structure of the industry in which they are operating in. In New Brunswick (and more broadly, Canada), all resources below the ground are owned by the Crown. Therefore, a royalty must be paid to the provincial government in order to extract the resources from its land. This is the government's share of resource rent. Revenues from the royalties (and license/leasing fees) are used to benefit the general population through investing the returns on government services like health care and education[77].

This type of input is unlike capital and labour in a few ways. First of all, it lacks a perfectly competitive market in which land resources can be traded. Access to natural gas supplies for producers depends not only on the economically viable supply, but on the institutional arrangements governing the disposal of rights to gas extraction[78]. This makes it nearly impossible to observe the true market price for the resource. Another important distinction made between this input and the others, is that at all points in time the supply must be considered fixed[79]. The level of extraction of a resource can be recalculated and modified over time, but with a much lower elasticity than other variables.

[77] New Brunswick Natural Gas Group. (2012). *Responsible Environmental Management of Oil and Gas Activities in New Brunswick: Sharing of Royalty Revenues from Natural Gas Activities in New Brunswick.* 4.
[78] Metcalf, C. (1996). *Resource Rents in BC's Forest Sector: A Historical View,* 4

This study will use the royalties paid to the province by drilling companies in the shale gas industry as a separate input to production in the model. Doing so will allow me to quantify to amount of shale gas exploration in the province in monetary terms.

5.2 Computable General Equilibrium Model

Economists employ a variety of tools when investigating policy impacts. This study will make use of a Computable General Equilibrium (CGE) model to estimate the potential economic benefits of shale gas exploration in New Brunswick from 2006 - 2026. CGE models are a great tool for policy analysis; as they use an economy-wide and market-based approach, where prices play a key role as the main mechanism through which supply and demand adjust following specified shocks[79]. CGE models use economic data to trace out in detail how an economy might react to changes in policy, technologies, markets, or other factors that can be built into the model.

CGE modeling began with the works of Johansen (1960), Shoven and Whalley (1972), and Miller and Spencer (1977). The complex design of these models was inspired as a result of the limitations to analyses conducted using input-output models to capture economic effects[80]. Input output models, such as the IMPLAN model discussed earlier, do not factor in how supply and demand effect prices, and consequently the spending behavior of consumers and producers. They also do not consider elasticities associated with the prices of intermediate inputs, export and import markets, and the cost of capital

[79] Ochuodho, T. Lantz, V. (2013). *Economic impacts of climate change in the forest sector: a comparison of single-region and multiregional CGE modeling frameworks.* Canadian Journal of Forest Research. Volume 44(5), 6
[80] Ochuodho, T. Lantz, V. (2013). *Economic impacts of climate change in the forest sector: a comparison of single-region and multiregional CGE modeling frameworks.* Canadian Journal of Forest Research. Volume 44(5), 7

and labour inputs. Therefore, they fail to reflect changes in the structure of the economy due to various factor prices.

CGE models can be modeled to analyze single-region or multi-regional economies. Though multi-regional models in theory produce a larger and more detailed analysis than single-region models, they are cumbersome to build and require additional assumptions and vast amounts of data. For the purpose of this study, I use a single-region model that is representative of New Brunswick.

Models can also be designed to be static or dynamic. A static model will generate results as a one-time snapshot of the change in economic variables at a given point of time – depending on the context, and how you have calibrated your data. This method holds levels of dynamic variables such as capital, labor, and resource stocks constant, which fails to reflect how the structure of the inputs in an economy change over time[81]. A CGE model must be solved under the "square matrix condition", meaning that the number of endogenous variables must equal the number of equations. Therefore, the model closure must be specified in a way to ensure mathematical solvability while reasonably reflecting reality and meeting the modeler's needs depending on the context of the analysis[82].

My model was based on the neoclassical modeling tradition originally constructed by Dervis et al. (1982), similar to the work of Das et al (2005). The model is built as a set of simultaneous linear and non-linear equations which define:

[81] Ochuodho, T. Lantz, V. (2013). *Economic impacts of climate change in the forest sector: a comparison of single-region and multiregional CGE modeling frameworks.* Canadian Journal of Forest Research. Volume 44(5), 8

[82] Ochuodho, T. Lantz, V. (2013). *Economic impacts of climate change in the forest sector: a comparison of single-region and multiregional CGE modeling frameworks.* Canadian Journal of Forest Research. Volume 44(5), 92

1) The behavior of economic agents;

2) Market conditions;

3) Macroeconomic balances;

4) Inter-temporal components.

In the model, producers are assumed to maximize profits (defined as the difference between revenue earned and the cost of factors and intermediate inputs and royalties) subject to constant returns to scale technology with two factors of production: labour and capital. Producers make their choice between factors via a constant elasticity of substitution (CES) function. This allows them to respond to changing factor prices by smoothly substituting from one factor to another in order to most efficiently produce a final value-added composite. Once the factors are determined, they are combined with fixed-share intermediates using a Leontief function. Fixed-shares are used for intermediates since their proportions are thought to be mostly determined by existing technology rather than producer decision-making. The price of final output in each sector is derived from the combined costs of value-added and intermediates[83].

Producers have the choice of purchasing intermediate inputs from the domestic market or from the foreign market following a CES Armington specification[84]. The final ratio of imports to domestic goods into New Brunswick is determined by the cost

[83] Ochuodho, T. Lantz, V. (2013). *Economic impacts of climate change in the forest sector: a comparison of single-region and multiregional CGE modeling frameworks.* Canadian Journal of Forest Research. Volume 44(5), 44

[84] Armington, 1969). Armington, P.S. (1969). *A theory of demand for products distinguished by place of production.* International Monetary Fund Staff Papers, 16(1).

minimizing decision-making of domestic consumers based on the relative prices of domestic goods and imports.

Substitution possibilities also exist between production for the domestic and the foreign markets. This decision of producers is governed by a constant elasticity of transformation (CET) function, which distinguishes between exported and domestic goods. Profit maximization drives producers to sell in those markets where they can achieve the highest returns. These returns are based on domestic and export prices.

The final composite good, containing a combination of imported and domestic goods, is supplied to both intermediate and final markets. Intermediate demand, as described earlier, is determined by technology and by the composition of sectoral production. Final demand, as described below, is dependent on household income and the composition of aggregate demand.

Households are assumed to receive income from supplying factors of production (labour, capital, and royalties), and from import tariff revenues transferred to them by their domestic governments. Supplies of capital and labour are typically assumed to be fixed within a given time-period and are mobile across sectors. Households save/invest a proportion of their income, and spend the remaining on consumption goods. All households are assumed to have identical consumption preferences, and are therefore modeled as 'representative' consumers. Consumer preferences are represented by a constant elasticity of substitution (CES) demand function, which is derived from the maximization of a utility function subject to a household budget constraint. Given prices and incomes, these demand functions define households' consumption of each commodity.

Production is linked to demand through the generation of factor incomes and tariffs and the payment of these incomes to households. Balance between demand and supply for both commodities and factors is established through a number of market closure assumptions, described later on.

Equilibrium in the goods market requires that demand for commodities equal supply. Aggregate demand for each commodity comprises household consumption spending on domestic and imported goods. Aggregate supply includes both domestic production and imported goods. Equilibrium is attained through the interaction of prices and the effect that relative prices have on sectoral production and employment, and hence household incomes and demand.

Equilibrium in the factor market requires that the demand for factors equal the supply. Equilibrium in these markets requires factor prices to adjust to ensure that demand equals supply. Finally, equilibrium in the current account requires that the value of imports equals the value of exports plus foreign savings. I fix foreign savings and exchange rates in the model, thereby requiring any change in the value of imports to equal that of exports. Finally, for equilibrium in the savings/investment account, it is assumed that the savings rates of households are fixed, and investment passively adjusts to ensure that savings equals investment spending in equilibrium.

CGE model results are sensitive to key parameters such as elasticities. However, there is little consensus among CGE modelers on the magnitude of these elasticities that would be considered ‘suitable’ under various modeling conditions (Arndt et al. 2002; Partridge and Rickman 1998; Shoven and Whalley 1984).

5.3 Model Specifications

For the purposes of this study, I have developed a dynamic, single-region model of New Brunswick, in order to capture the dynamic effects of this type of shock. The CGE model was solved using the General Algebraic Modeling System[85] software along with the CONOPT3 solver. The model parameters, variables, and equations are presented in the Appendix. Each regional CGE model requires an input-output (IO) table and a series of capital-labour, import, and export substitution elasticity estimates for each time period. This study uses the input-output data are compiled by Ochuodho and Lantz (2015). Data was acquired from Statistics Canada's input output tables and the GTAP data base. Specific benchmark data used in the model were obtained from 23 distinct sectors within New Brunswick economy, including: respective values for exports, imports, import tariffs, value added components (labour and capital), final consumption, final investment, and intermediate consumption. The sector that this study focusses on is Mining, Quarrying, and Oil and Gas Extraction from the North American Industry Classification System[86].

Using the data obtained from Statistics Canada on the 23 sectors as defined by NAICS, capital was estimated as the sum of operating surplus, indirect taxes on products, subsidies on products, other subsidies on production, and other indirect taxes on production less land resource rent (described later). Labour was estimated as the sum of

[85] GAMS. (2010). *General Algebraic Modeling System.* GAMS Development Corporation.
[86] Statistics Canada. (2016a). *North American Industry Classification System (NAICS) Canada 2012.* [online]. Available at: http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=118464&CVD=118465&CPV=21&CST=01012012&CLV=1&MLV=5

wages, salaries, supplementary labour income, and mixed income. Unemployment rate data were obtained from Statistics Canada's provincial labour force survey estimates[87].

For parameter specifications, elasticities of substitution in the composite value-added function were obtained from Dimaranan et al. (2006). Armington, CET elasticities and import tariffs were obtained from GTAP database following sectoral aggregation[88].

The marginal rate of consumption for commodities was assumed to remain unchanged over time, meaning that new consumers had the same preferences as existing consumers. Technological progress was assumed to be labour-augmented, so the model reaches a steady state in the long run[89]. Finally, available resource stock supply in Mining, Quarrying, and Oil and Gas extraction sector was exogenously fixed over time under baseline conditions. This was in order to create a baseline path where the exploration of shale gas does not increase over time from 2006 onward.

My CGE model was formulated as static and solved recursively (sequentially) over 20-year (2006-2026) period. For every period run, capital stock was updated via a capital accumulation equation which is based on an endogenous growth rate as determined by endogenous return on capital rate and endogenous total savings (following Chang et al. 2012; Alfsen et al. 1996). Total labour supply was assumed to grow exogenously at a constant rate over time. The growth rate that was chosen for this study was based on projections compiled by Statistics Canada[90].

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[87] Statistics Canada. *Table 282-0001 - Labour force survey estimates (LFS), by sex and detailed age group, unadjusted for seasonality, monthly (persons unless otherwise noted),* CANSIM (database).
[88] Dimaranan et al. (2006). *Behavioral parameters in Global trade, assistance, and production.* The GTAP 6 database. Chapter 20.
[89] Zhai et al. (2009). *A general equilibrium analysis of the impact of climate change on agriculture in the People's Republic of China.* Asian Dev. Rev. 26(1).
[90] Statistics Canada. (2010). *Population Projections for Canada, Provinces and Territories.* Catalogue no. 91-520-X.

After solving the models for the initial period equilibrium to replicate the 2006 benchmark IO data, I simulated two categories of economic scenarios, including: (i) a baseline (without shale gas exploration) scenario; and (ii) growth paths with two different growth rates of natural gas extraction in New Brunswick. These growth rates were quantified using royalty revenue projections, which are explained below. For the baseline scenario, I simulated a dynamic growth path of the economy where economies grow based on exogenous labour supply growth rates and endogenous capital investments, and resource rent remains constant at 2006 levels.

In order to quantify the shock to natural gas extraction in New Brunswick, data from the provincial public accounts[91] is used to determine the amount of royalties (and exploration license) fees that were paid to the crown by natural gas extraction companies operating in the province. Implicit in this style of shock is the assumption that all natural gas in the province is extracted from reservoirs in shale formations, when this is not the case. There are a number of "tight gas" reservoirs in New Brunswick; however, virtually all of them require some degree of hydraulic fracturing in order to extract the gas inside[92].

After obtaining the amount of royalties paid from companies exploring natural gas in the province, I extract this value out of the cost of capital in this sector, which allowed me to isolate it a separate input into production. By establishing royalties, or "rent", as a separate input, I allowed the model to determine the initial factor ratios of labour, capital, and royalties. This method was best suited for our shock as all of the inputs to this model are denominated in dollar values, and there have already been

[91] Government of New Brunswick. (2007). *Public Accounts: for the fiscal year ended 31 March 2006*. Volume 2. Supplementary Information.
[92] World Oil. (2011). *Propane-based fracturing improves well performance in Canadian tight reservoirs.* [online]. Available at: http://www.gasfrac.com/assets/files/World%20Oil%20Article.pdf

projections of the total cumulative value of provincial revenue from royalties in New Brunswick over a 20 year period[93]. By using the total royalty revenue in 2006, and the two 20 year cumulative revenue projections ($1 billion and $1.5 billion), I determined a constant annual growth rate for each scenario. It should be noted that the projection that was found was $1.5 billion; I chose $1 billion as a lower bound to ensure that our estimates were conservative.

6 Results

6.1 Macroeconomic Indicators

The following tables display the impacts to the key economic variables in this study, GDP, consumption, investment, labour expenditures, capital expenditures, imports, exports, and total domestic production. Table 1 shows the economic growth under the baseline growth condition:

Table 3:

Baseline scenario data: 2006 and 2026 (current $Billion)

Variable	**2006**	**2026**	**Difference**
GDP	25.50019	25.7348	0.23
Consumption	22.76774	22.73863	-0.03
Investments	6.619375	6.663068	0.04
Labour expenditures	15.92908	16.34015	0.41
Capital expenditures	9.514132	9.800899	0.29
Imports	23.94981	23.72907	-0.22
Exports	20.06	20.10581	0.05
Total domestic production	57.6149	57.72227	0.11

[93] Jupia Consultants Inc. (2014). *Potential New Brunswick Energy Infrastructure & Natural Resource Investment Review (2015 – 2020)*, 25

Only modest economic growth is expected to unfold over the 20-year period under baseline conditions. Tables 2 and 3 compare cumulative present values of the growth scenarios with the baseline scenario

Table 4:

Baseline vs Shale gas medium growth scenario values (Cumulative present value $Billions; 2006-26)

Variable	Baseline	Medium growth	Difference
GDP	347.8717	362.9128	15.04108
Consumption	308.8683	367.4932	58.62485
Investments	90.19402	95.51443	5.320407
Labour expenditures	218.4531	273.6433	55.19023
Capital expenditures	131.5005	131.4014	-0.09913
Imports	322.0803	341.8332	19.75294
Exports	272.839	292.5919	19.75294
Total domestic production	782.9586	917.8999	134.9413

Table 5:

Baseline vs Shale gas high growth scenario values (Cumulative present value $Billions; 2006-26)

Variable	Baseline	High growth	Difference
GDP	347.8717	363.6776	15.80592
Consumption	308.8683	367.0797	58.2114
Investments	90.19402	96.84634	6.65232
Labour expenditures	218.4531	276.0324	57.57926
Capital expenditures	131.5005	131.3997	-0.10076
Imports	322.0803	342.8427	20.76249
Exports	272.839	293.6015	20.76249
Total domestic production	782.9586	920.0576	137.099

The increase in shale gas extraction over the 20 year period had the greatest impact on total domestic production. Under both of the growth scenarios, domestic production results in over $130 billion in domestic production, cumulatively over 20 years. Although this signifies a massive increase in production within New Brunswick, not all of impact is absorbed into provincial GDP.

6.2 Market Interpretations

Cumulative GDP is roughly $15 billion more under the shale exploration growth scenario, which is considerably less than the increase in domestic production. Evaluating GDP on a net-output basis is one possible avenue of explaining this. Breaking GDP down this way allows you to examine exports less imports, investment, consumption, and intermediate output less intermediate use in the primary market.

First, I will look at exports and imports. Net exports are unaffected by shale gas exploration under the growth scenario; this can either be attributed to a lack of specification in the model, or a number of other factors. Although net-exports are unchanged, the absolute values of both imports and exports showed increases under the shale gas scenario. The fact that they were exactly equal in magnitude is attributed to an assumption implicit in the model; such as the current account equilibrium condition whereby the economy in the model maintains its initial net trade balance. With that assumption aside though, there is a possibility that this could be indicative of a high domestic demand by both consumers and industries, which would imply that the elasticities in the composite-value-added function and the income elasticities of demand for commodities (in this sector) were extremely responsive. The fact that consumption was greater than trade in the shale gas scenario offers some support for this idea.

Next, I will look at investment. Capital expenditures turned out to be lower in the scenarios that included shale gas exploration than in the baseline growth path, even though investments had both grown. It is possible that this could be representative of a shift in the industrial demand for natural gas as a source of power or intermediate input to production. It could be that investors and industries capitalized on the benefits of a natural gas source by increasing their investment into new technologies that would allow them to adapt to a new energy supply. Although capital expenditures will have initially increased in the Mining, Quarrying, and Oil and Gas Extraction sector, the new abundant supply could have put downward pressure on the price of commodities (natural gas, in this case) produced in this sector. This would effectively reduce the cost to other industries that require output from this sector as intermediate input into their sectors, and allow them the opportunities to generate savings through reduced capital expenditures.

The second highest impacted variable from shale gas exploration was consumption, which was roughly $58 billion higher under the shale scenario. Equilibrium conditions in the model require that the demand for commodities equals the supply, and consumption of each commodity will increase as incomes increase and prices decrease. Goods and services produced domestically are either exported to foreign buyers, or are purchased from households or domestic industries. The shock in natural gas production was substantial in our model, and a proportionate increase in labour expenditures was required in order for production levels to sustain the high level of growth. The increase in labour expenditures brought on by shale gas exploration is almost equal to the increase in consumption under the shale scenario, which explains a majority of the consumption levels.

From the results of the model, the most noteworthy impact of shale gas exploration in New Brunswick is in the primary market, in which commodities are bought and sold among firms as intermediate consumption as an input to production. It is evident from level of total domestic production and the breakdown of GDP in Tables 2 and 3 that a great share of the output from this shock has gone towards satisfying industrial demand in the primary market. It is crucial to note that the impact of shale gas exploration in New Brunswick would have a significant effect on provincial exports and imports; but for the sake of simplicity in the model, I assumed a balanced trade account. This condition in all likelihood over-stated the impact that the shock had on consumption, as much of what would have gone to exports was forced to be sold to domestic markets in order to reach a general equilibrium.

6.3 Model Commentary

Although a few assumptions (as noted in earlier sections) were made in order to simplify the model, it should be noted that further work and specification could substantially address these issues. All in all, enough specifications were made to confidently conclude that there would be substantial benefits to the province if it were to partake in shale gas exploration. A further analysis into quantifying the negative attributes of shale gas exploration is warranted if a policy committee was ever to consider taking this approach in evaluating hydraulic fracturing.

The methodology and results of this model is in line with the findings of previous research and manages to avoid some of the criticisms received by alternative methods. Where Considine et. al (2009) rely on a private survey of that only received data from seven of thirty-six firms, this study makes use of Statistics Canada's national database. This database does suppress confidential data at low levels of output; however, when taken at the aggregate provincial level provides a reliable estimate of economic activity.

My model also specifies the behaviour of economic agents, including household consumption and saving patterns. This was not accounted for in the results of the IMPLAN input-output model used by Considine et. al (2009), where they assumed that all income payments to households through wages, interest, and royalties were spent in the same year that they were earned – in spent within the state of Pennsylvania, at that. My model allows households to consume, invest, and save given their preferences in order to maximize their specified utility. Their spending behaviour is also influenced by the change in prices over time, and they are not limited to the domestic market as they are free to export and import where it is more economical. These behavioural features are shared with producers, which allow the model to account for leakages in the supply chain through imports, intermediate consumption, and value-added components.

The IMPAN model is also inferior to CGE analysis, as it does not account for supply limitations and the crowding out effect. Labour and capital are set to fixed levels in the initial base year, and can only grow as was specified in previous sections. The only other method by which labour supply could all-of-the-sudden satisfy production demand is through employing the portion of supply that is initially unemployed. This process, however, is subject to the conditions of the Phillips curve that are imposed in the model, thereby allowing for more realistic transitions in the labour market.

My CGE model is also free of any errors that could arise from double counting, a problem faced by researchers using input-output models for any magnitude of shock that is considered more than marginal.

7 Conclusions

The results of this study come as little surprise – there are certainly net-economic benefits to shale gas exploration in New Brunswick. Although the model did not cover the impact to net-trade, it was able to show an increase in exports for the province. It is possible to speculate that without the trade equilibrium condition in place the increase in exports would have surpassed the increase in imports, but without results to back this up, the discussion will be saved until further research is done. It could also be the case that if these were not in equilibrium, there would have been a greater increase in imports if domestic suppliers do not have the adequate material to provide to shale gas companies.

It is quite likely that with the increased production in the drilling sector, a necessary amount of labour and capital were diverted from other industries in order to satisfy the model's conditions. In reality, there is no guarantee that the work skills in the existing sectors are transferable to this type of production. Some of the labour required for shale gas exploration may in fact come from outside the province; and depending on the structure of employment and the length of certain projects, the income earned from this imported labour will flow out of the province.

Given the estimates on the total supply of shale/tight gas in the province, it is unlikely that New Brunswick would be concerned over a boom-bust cycle. Given its current economic performance, it would likely be warm to the idea of an influx of workers. In fact, increasing immigration is already underway in New Brunswick and Atlantic Provinces through a pilot project aimed at increasing their labour forces by matching the needs of current employers with the skills possessed by immigrants in the program[94].

The impact on the primary (intermediate) market that this model produced should also be analyzed in context with New Brunswick. The results in the model indicate that the intermediate (industrial) demand for output produced from the gas extraction industry increased substantially when production increased. As mentioned before, earlier studies have observed structural changes in businesses that operate in proximity to shale gas exploration. This can happen by businesses capitalizing on a cheaper and closer energy source by converting their facilities, machinery, or equipment such that they are fueled by natural gas. In the case of New Brunswick, increased levels of shale gas extraction could

[94] The Globe and Mail. (2016). *Atlantic premiers, Ottawa announce pilot project to boost immigration.* [online]. Available at: http://www.theglobeandmail.com/news/politics/atlantic-premiers-ottawa-announce-plan-to-boost-immigration/article30739787/

entice NB Power to convert their generation stations into gas-powered stations. Consumers would experience pass-through savings if NB Power were to efficiently capitalize on the opportunity. It could even be the case that shale gas exploration would entice companies like PotashCorp to reconsider a mining project in New Brunswick, as discussed earlier.

Having said all this, it is unlikely that New Brunswick will consider shale gas exploration anytime soon. Even if a new technology was created that could completely mitigate any damage to the environment, the price of gas is just too low for most companies to justify entering the market. Although it looks to be an opportunistic resource for the province, its discovery may have come a few decades too late. Society now exerts a commendable amount of care towards its environment, and its dedication to innovating new technologies and alternative fuel sources grows more sincere as time moves forward. By the time the market conditions rally in its favour, shale gas in New Brunswick may be moot point.

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