Skills, Tasks, and Energy Booms

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Abstract

While secular skill-biased changes to the wage structure have been and continue to be widely studied in the economics literature, cyclical skill-biased changes have been largely overlooked. The current paper explores this subject by measuring the impacts of a large and localized cyclical shock from a recent energy boom on the local labor markets of Canada. This shock lead to an increase in the routinization and manualization of tasks across the occupational distribution, with routinization having a significant and positive impact upon wages, opposing the documented secular trends away from routinization. These demanded tasks are filled by workers from the lower and middle portions of the skill distribution, particularly by trades and apprenticeship graduates. However, the supply of this group actually decreases during this boom, with the wage gains spreading out further along the skill distribution, suggesting some imperfect substitution between skill groups. This skill-biased change of the energy boom runs counter to the documented secular change of polarization away from the middle and towards the tails of the skill distribution.

Keywords: cyclical vs. secular, energy booms, skill-bias, tasks, wage structure.
JEL Codes: J20, J24, J40, R23, Q33.

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1 Introduction

Secular skill-biased changes to the wage structure under the canonical model have generally favored high-skilled workers due to skill complementarity and disfavored low-skilled workers due to skill substitution, thereby raising the skill premium between them. The adoption of technology, the phenomenon of off-shoring, and certain trade patterns are all such changes that have been widely studied in the literature, following the seminal work of Katz and Murphy (1992). More recent advances in this literature, brought together by Acemoglu and Autor (2011), have distinguished between the skills available and the tasks performed in the labor market, as well as introduced semi-skilled employees into this framework. The skill-specific task assignments have been especially crucial in the understanding of these changes, as summarized in Autor (2013). And, the addition of the middle skill group allowed for the examination of the more recent finding that it is the middle class which is being replaced by technology, while the demands for low and high skilled individuals are both increasing, leading to polarization (Foster and Wolfson, 2010; Acemoglu and Autor, 2011; Autor and Dorn, 2012).

Cyclical skill-biased changes, on the other hand, have been largely overlooked. However, their importance to the wage structure may potentially be more substantial than secular skill-biased changes, especially in cases where the cyclical impacts are large and localized. In this context, the current paper explores the subject of an energy boom as a particularly potent skill-biased cyclical change to determine whether this change affects the wage structure in a different or similar manner to those secular changes. Within the literature, there is little known about the possible labor market impacts of such energy booms. The current paper explores this question by investigating the impact of the most recent energy boom across the local labor markets of Canada. Because of the importance of the energy market in the Canadian economy, these boom impacts are expected to be particularly substantial, providing a good framework for identification. The focus of the current study is therefore to identify the skill-specific local labor market impacts of these cyclical energy booms, in order to determine which groups of workers gain relative to others.

When a resource-rich economy experiences an energy boom, local labor demand receives a positive shock across all industries, although this impact is particularly large for those working within the energy extraction sector. This positive demand shock for labor increases its price, in the form of wages and earnings, and it increases its quantity, in the form of increased work hours and new employment in the labor force, in order to accommodate the excess demand. Marchand (2012) showed the mechanism and magnitude of this phenomenon in the Western Canadian region over the previous two energy booms. While the paper had showed that the labor demand shocks of each boom had drastic impacts upon the local labor markets of Western Canada, it assumed that these impacts were uniform across the entire spectrum of skills and tasks, which is unlikely to be the case. These differential impacts should be even more prominent if the local markets with energy resources rely upon labor-intensive tasks that requires a specific skill set.

For example, the positive labor demand shock of this energy boom may generate a higher demand for tasks needed in the directly-impacted energy extraction industry, such as those performed by equipment operators, welders, or cutters. If an energy boom is skill-biased, the demand for one type of skill will increase relatively more than the other types. If middle-skilled workers are the best fit for performing these particular tasks, then the wages for that particular skill group should increase accordingly. This differential impact is expected to be larger when the boom effect is large in magnitude, long in duration, and highly localized. If the wage gains extend beyond that particular skill group or if that skill group is not readily supplied, there could be imperfect substitution between skill groups. This mechanism could work very much like a skill-biased technological change, though a skill-biased energy boom may not be biased towards the high-skilled (due to technology being complementary for this worker type) and away from the low-skilled (due to being substitutable for this worker type). Rather, the skill-biasedness of an energy boom is hypothesized to favor the middle of the skill distribution, as opposed to the documented polarization between low and high-skilled workers in the tails of the distribution. This aspect of energy booms has not been previously investigated, and the current paper stands to contribute to the literature by providing a thorough investigation of these skill-biased aspects of energy booms.

2 Data and methodology

2.1 Data source, sample, and outcomes

The Research Data Centre (RDC) version of the Canadian Census of Population, administered by Statistics Canada, is used to construct the labor market outcomes for this study. This census is designed as a quinquennial survey, containing detailed information about the demographic and economic characteristics of individuals living in Canada. Each survey represents a twenty percent sample of the population, with a full representation of the entire Canadian population provided through the use of sampling weights. The main advantage of this Census data is that it has a large number of individuals needed to fill in the cells necessary for this type of analysis when examining the data by geography, occupation, or education. And, the restricted-access version of this Census data allows for a richer selection of the necessary geographical, educational, and occupational descriptors to construct these cells.

The initial sample of individuals is limited to employed, paid civilians, thus eliminating those that are unemployed, not in the labor force, not paid, or not civilians (i.e. those in the armed forces). The sample is limited demographically to males between the ages of 15 to 64 years old.[1] This sample is further limited to full-time, full-year workers, meaning those that worked 30 hours or more per week and 40 weeks or more per year, respectively.[2] These restrictions are set in place to bring the study in-line with the previous literature and to limit the effects of part-time or seasonal work, as well as any gender-related issues or other phenomena outside of the subject at hand. After all of these limitations are set in place, there are roughly one million, unweighted individual observations available per wave.

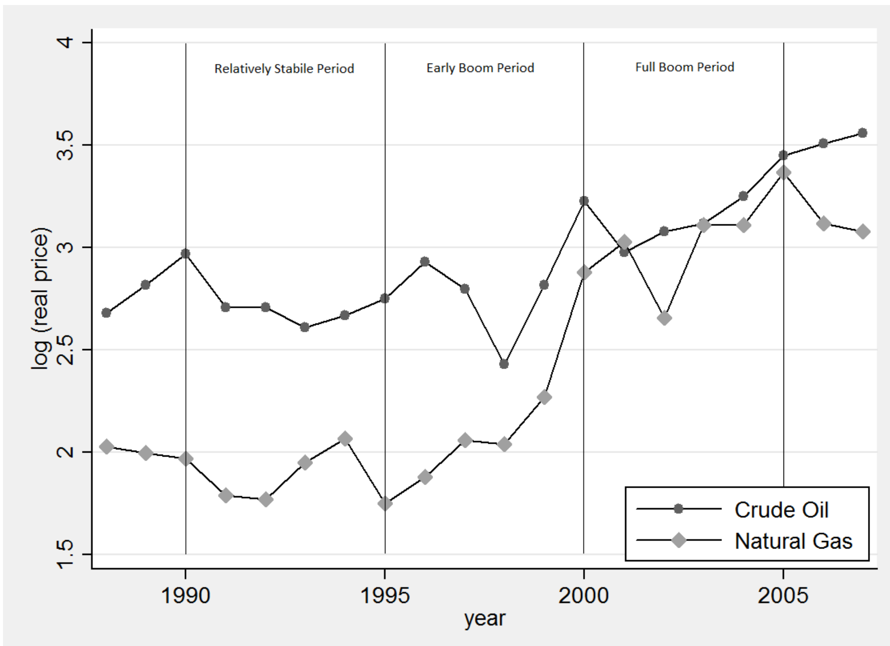
There are four Census waves used in this study, which were collected in 1991, 1996, 2001, and 2006. Each Census wave contains responses corresponding to the previous calender year, so the 2006 Census wave contains responses for 2005, for example. These four Census waves are consolidated into three intercensal time periods of interest: 1990-1995, 1995-2000, and 2000-2005. These three distinct time periods resemble the gradual stages of the energy boom process, from changes occurring immediately prior to, changes during the build up to, and changes during the full stage of, the most recent energy boom over the mid-1990s to the mid-2000s. As

[1]This is a slight departure from the U.S.-based studies, which instead use 16 years of age as the lower bound. Canada uses the age of 15 for eligibility to work, and this study follows from that.

[2]The use of 30 hours per week cut-off for the full-time designation is a slight departure from the U.S.-based literature, which instead uses 35 hours per week for this purpose. The current study chose to follow the 30 hour cut-off due to the Canadian Census definition of a full-time worker.

shown using the real energy price trends of crude oil and natural gas in Figure 1, the 1990 to 1995 period serves as the relatively stable years, due to the stagnation of these commodity prices during this time. The energy prices then began to sharply increase from 1995 to 2000, defining the early boom years, and continued to increase from 2000 to 2005, representing the full boom years.

Figure 1: The rising intensity of the energy boom through real energy price trends over three distinct periods



Notes: Author's calculations of 1988-2007 public-use Canadian Association of Petroleum Producers data. The log real price of crude oil is based on the average wellhead price in dollars per cubic meter. The log real price for natural gas is based on the average wellhead/plant gate price in dollars per thousand cubic meters.

There are two main labor market outcomes examined in this analysis: employment shares and hourly wages. Employment shares for any particular group are calculated as the aggregate amount of hours worked accruing to that group of workers as a share of all aggregate hours worked across all workers.[3] The annual work

[3]While either the total employment count or the total hours worked could be used interchangeably to represent this employment share, the results do not vary greatly between these definitions. As noted in the discussion of bodies versus hours in footnote 8 on page 1049 of Acemoglu and Autor

hours used for this outcome are first found by multiplying the individual responses for the number of weeks worked in the calender year by the number of hours worked in the reference week prior to the Census day. Hourly wages for any particular group are calculated as the average over that group of workers.[4] This wage outcome uses the responses for annual earnings over the calender year divided by the constructed annual work hours described above.[5] These wages are set in real terms to maintain consistency across time by deflating the nominal wage values by the Canadian consumer price index, so that all values are represented in 2005 dollars.

2.2 Identification using geographies and local labor markets

The local labor market definition of this study is set at the level of economic region.[6] This definition generates a number of geographical areas similar to the number of local areas used in the previous literature, relative to the differences in population sizes between the U.S. and Canada. For example, Autor and Dorn (2009, 2012) use over 700 commuting zones to represent the roughly 300 million individuals living in the U.S., while the current study uses over 70 economic regions to represent the roughly 30 million individuals living in Canada.[7] Concordance is kept between the economic regions across the four waves of Census data by integrating all of the changes at the smaller Census subdivision level over time using the 2006 boundaries. All geographic descriptors are based on the location of the current residence for the respondent in each wave.

There are three different sets of local labor markets used in this study, in order to establish the sources of the employment changes as either cyclical or secular, or in

(2011), only second-order differences will appear between the two. This distinction also does not matter that much for the evidence of the current study.

[4]Weekly wages could also be used interchangeably with hourly wages in this study, which would be constructed by dividing the annual reported wages by the number of reported weeks worked.

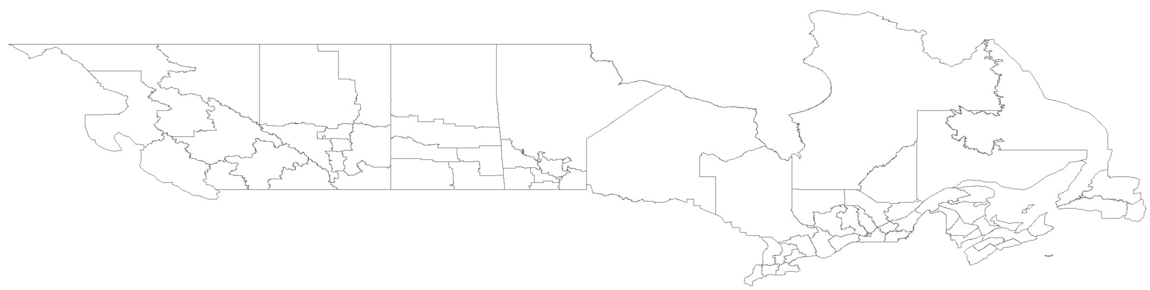
[5]The hourly wage measure could also be truncated in the tails of the distribution to dispel any outliers in the data. For example in Acemoglu and Autor (2011), hourly wages of below \$3.41 an hour in 2008 dollars are dropped, as are wages above 1/35th of the top-coded value of weekly earnings, and weekly earnings of below \$136 per week in 2008 dollars are dropped. One possibility for the current study would be to truncate the wage distribution by cutting one to three percentiles from each tail of the wage distribution, but this has not been done yet.

[6]The local labor markets of this study are at the economic region rather than the Census division level of Marchand (2012) and are therefore larger areas with more people. So although there are less local labor markets altogether, there are more individuals to work with within each cell. This is done in order to more closely examine labor groups within each local labor market.

[7]One possible weakness of using economic regions for Canada instead of their commuting zones for the U.S., however, is that all economic regions are contained within Canadian provinces while commuting zones are allowed to span across U.S. state boundaries.

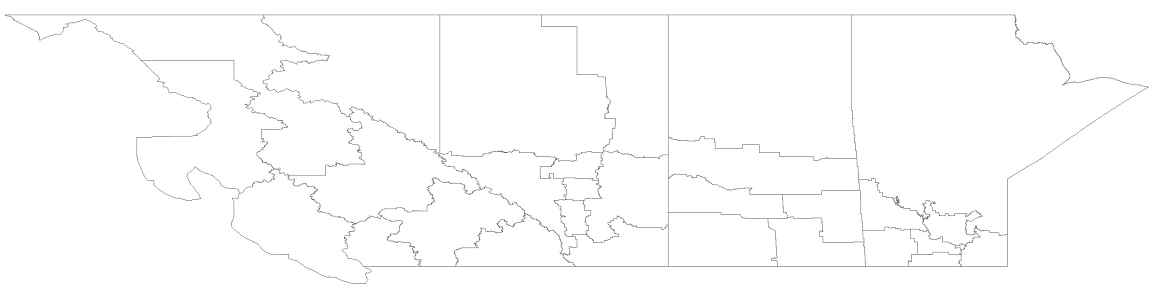
other words, attributable to the energy boom or not. The energy set of local labor markets serves as the treatment group representing the cyclical changes generated by the labor demand shock of the energy boom. The regional and national sets of local labor markets serve as the comparison groups which do not receive this shock and are used to represent any secular changes taking place in the overall economy. As shown in the coming evidence section, what is going on in the local labor markets of the energy set is quite different from what is going on in the western region or nationally.

Figure 2a: Economic regions of Canada



Notes: Author's calculations using the 2006 Census wave division boundaries.

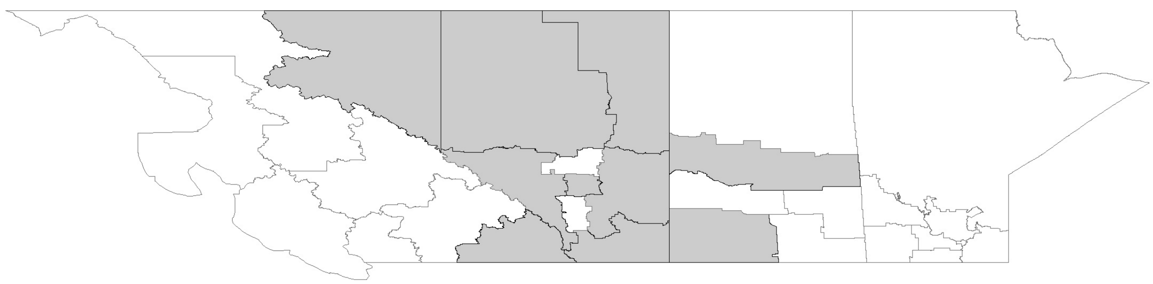
Figure 2b: Economic regions of Western Canada



Notes: Author's calculations using the 2006 Census wave division boundaries.

All ten of the Canadian provinces comprise the national set for Canada: Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Quebec, and Saskatchewan. However, this national set excludes the three Canadian territories, which are the Northwest Territories, Yukon, and Nunavut, due to their relatively small populations and lack of geographical disaggregation as compared with the provinces. Four of these provinces comprise the western region of Canada: Alberta, British Columbia, Manitoba, and Saskatchewan. There are seventy-three economic regions at the national level, as shown in Figure 2a, and there are thirty economic regions in Western Canada, as shown in Figure 2b.

Figure 2c: Economic regions of Western Canada with energy resources



Notes: Author's calculations based on 1996 Census wave data using the 2006 Census wave division boundaries. The decision rule was based on having more than five percent of total earnings from energy extraction in the base year of 1995. One economic region was omitted for being a major city, which was ER No. 4830 for Calgary, AB.

The energy set is based on the percentage earned from the energy extraction sector over all earnings within a local labor market being over the threshold of five percent. This threshold used in the current study lies between the 10 percent threshold used at the smaller U.S. county and Canadian Census division levels of Black, McKinnish, and Sanders (2005a) and Marchand (2012), respectively, and the 2 percent threshold used at the larger state level of Blanchard and Katz (1992). Also, the base year used to define the fraction of total earnings from energy extraction is the 1996 Census wave, which is the same base year used for the second boom period in Marchand (2012). There are ten economic regions which are considered the energy areas receiving the treatment of the energy boom shock, as shown in Figure 2c. In Appendix Table A1, the fractions for these energy extraction earnings are shown to have grown in all economic regions of the energy treatment group over the previous energy boom, with the exception of the top two economic regions, which declined slightly. In addition, although the energy areas were allowed to come from all ten provinces rather than just the four western provinces, all happened to be located within the western region.[8]

[8]Certain geographical portions of Quebec and the Maritimes also represent an emerging energy

3 Demand for tasks due to the energy boom

3.1 Employment across tasks and occupations

The evidence in this paper is a combination of descriptive analysis, used to represent the broad changes happening to employment and wages due to the energy boom, and regression analysis, used to more precisely determine the magnitude of these changes attributable to the boom. Because an energy boom provides a positive shock only to local labor demand, this evidence is first presented for the demand-side of the labor market, across the task and occupational distributions. An energy boom should lead to a relative increase in the demand for only the certain tasks and occupations that need to be accomplished, especially within the local labor markets that contain these resources. Once these tasks and occupations that are most directly in need on the demand-side are determined, only then can the educational distribution be examined, which is done in the next section.

The task and occupational distributions are formed from the approximately 500 occupations available in the Census data, while maintaining consistency over time in these codes between the four survey waves. The demand-side evidence focuses on the task-content of these occupational changes. Autor (2013) emphasized the critical importance of using task categories instead of only using occupation groups. Four task groups are constructed which are ranked from the top to the bottom of the task distribution. These tasks are non-routine cognitive, routine cognitive, routine manual, and non-routine manual. Ten aggregate occupational groups are also constructed and ranked from the more cognitive to the more manual task-content, where the middle of the distribution represents the relatively more routine tasks and the tails of the distribution represent the relatively more non-routine tasks. Both of these categorizations for tasks and occupations follow from those used in Acemoglu and Autor (2011).

Each task group contains two or three of the aggregate occupation groups. At the top of the distribution are the non-routine cognitive tasks, including the aggregate occupations of managers at the top, then professionals, and then technicians. The routine cognitive tasks are next in the distribution, which includes the sales and the office and administration occupations. In the lower half of the task distribution, routine manual tasks are covered by the aggregate occupations of production, craft, and repair, and then operators, fabricators, and laborers. The non-routine tasks are at the bottom of the distribution and comprise protective services, then food prepa-

sector in Eastern Canada, but it is not enough to fit the definition for this study during this period of time.

ration, buildings and grounds, and cleaning, and lastly, personal care and personal services.

Table 1: Employment shares and percentage point changes by task group

	Employment Share				Δ Employment Share		
Nation:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	37.67	37.67	40.05	39.46	-0.00	+2.38	-0.59
Routine cognitive	14.89	15.63	12.82	13.23	+0.74	-2.81	+0.41
Routine manual	36.94	35.97	37.26	37.13	-0.97	+1.29	-0.12
Non-routine manual	10.48	10.71	9.85	10.16	+0.23	-0.86	+0.31
Western:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	37.76	37.46	40.20	38.64	-0.30	+2.74	-1.56
Routine cognitive	14.36	15.23	12.13	12.18	+0.86	-3.09	+0.04
Routine manual	37.34	36.49	37.44	39.23	-0.85	+0.95	+1.79
Non-routine manual	10.52	10.81	10.20	9.93	+0.29	-0.60	-0.27
Energy:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	30.90	30.08	30.76	28.11	-0.82	+0.68	-2.65
Routine cognitive	9.52	10.81	8.29	8.68	+1.29	-2.51	+0.38
Routine manual	50.20	49.72	52.78	55.37	-0.47	+3.05	+2.59
Non-routine manual	9.36	9.37	8.14	7.82	+0.01	-1.22	-0.32

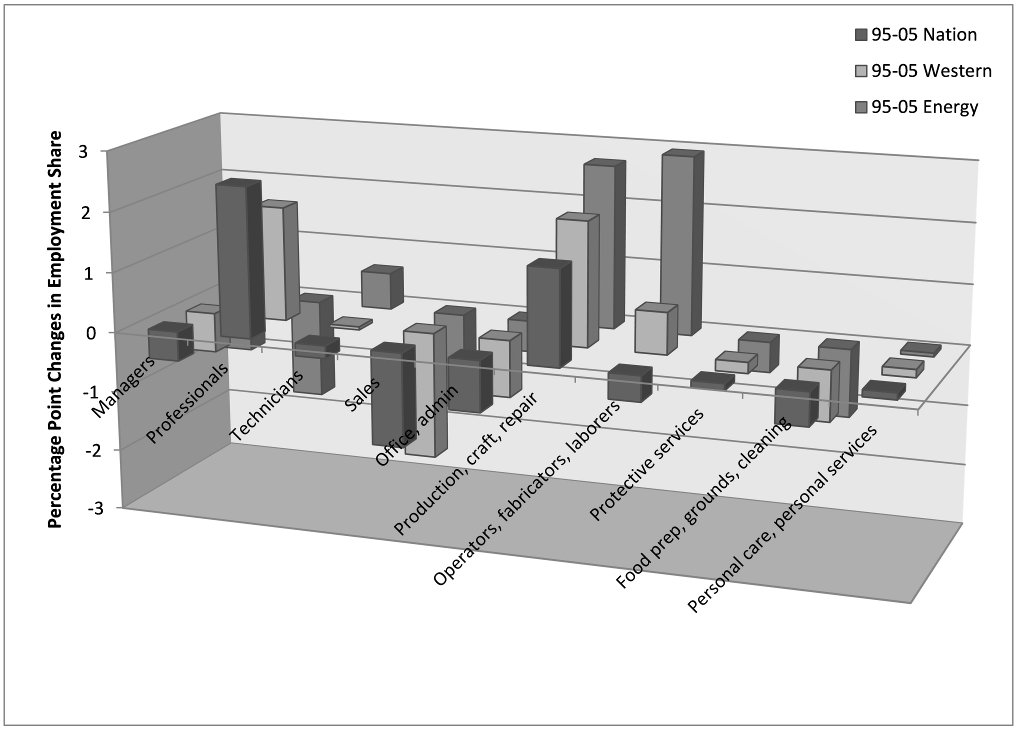
Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

The concentration of employment is shown over the distribution of tasks in Table 1. The average employment shares are presented for each task by geographical set and year in the first four columns and then, in the last three columns, the percentage point changes taking place over each time period are shown. In the national and regional geographies in 1990, slightly more than a third of workers were employed in non-routine cognitive and routine manual tasks. Of the remaining quarter of employment in these areas, a larger share was dedicated to routine cognitive than non-routine manual jobs. The composition of employment in the energy set is drastically different. Routine manual tasks comprise half of the employment in energy areas, with non-routine cognitive tasks making up thirty percent and the remaining employment evenly split at roughly ten percent each between routine cognitive and non-routine manual tasks. Further comparing the geographical areas, non-routine cognitive and routine tasks comprise more of the national and regional employment, while routine manual tasks comprise more of the energy area employment, with non-routine manual employment being somewhat similar between the geographies.

These employment concentrations did not change by much during the relatively stable period from 1990 to 1995, regardless of the geographical grouping. That said, the largest decrease during this period came from routine manual tasks, at the regional and national levels, and from non-routine cognitive tasks in the energy areas, while the largest increases were consistently in routine cognitive tasks across all three geographies. The largest set of changes in employment share along the task distribution occur during the early boom period from 1995 to 2000, regardless of geography. In this period, all three geographical groups experienced drastic relative declines in routine cognitive employment and, to a lesser extent, non-routine manual employment. But, the largest increases in this period were for non-routine cognitive at the regional and national level, and routine manual for the energy areas. Once the full boom takes place from 2000 to 2005, there was a continued movement toward routine employment and a new movement away from non-routine cognitive tasks in the energy areas. This pattern is replicated for the western region, albeit at much smaller magnitudes than the energy areas. The pattern at the national level differs from the other geographies though, with changes smaller in magnitude than the other two geographies.

Most importantly, the employment share changes in the energy areas during the energy boom are shown to favor the lower middle portion of the task distribution, increasing the demand for routine and manual tasks and reducing the demand for non-routine and cognitive tasks. These huge increases in the demand for routine manual tasks in the energy areas are consistent over the early boom and full boom periods, with a 3.05 percentage point increase and a 2.59 percentage point increase respectively, implying that neither of the boom periods has a larger effect than the other. These demand increases were mostly at the expense of routine cognitive and non-routine manual tasks in the early boom and the non-routine cognitive tasks during the full boom. By 2005, the percentage employed in routine manual tasks, which was already half of employment in energy areas, increased even further, while relatively decreasing employment at both ends of the task distribution. This cyclical impact on the distribution of tasks is the exact opposite of the polarization brought on by skill-biased technological change and other secular skill-biased changes happening in recent decades.

Figure 3a: Employment changes along the occupational distribution over the boom



Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

The percent point changes in relative employment shares across the aggregate occupational categories is shown over the combined 10-year boom period in Figure 3a. At the national level in the foreground, the largest employment share increase during the boom is for professionals, while the largest decrease is for the sales occupation. There is also a moderate increase in production, craft, and repair employment and a moderate decrease in that of office and administration. No other discernible pattern is observed for this geography, with especially little change happening in the bottom half of the occupational distribution. These occupational changes are replicated for the western region, with slightly less of an increase for professionals, slightly more of a decrease for the sales occupation, and a slightly larger increase for production, craft, and repair. The differing pattern during the boom for the energy areas relative to the other two geographies becomes even clearer when examining these changes along the occupational distribution. Both of the occupations performing routine manual tasks experience large relative increases, with the increase for production, craft, and repair being of somewhat larger magnitude than for the region and nation and the increase for operators, fabricators, and laborers being the most drastic increase by comparison. The energy areas also experience a noticeable relative employment loss in the occupations of managers, professionals, and sales at the upper end of the distribution and for protective services and food preparation, grounds, and cleaning at the lower end of the distribution.

3.2 Wages along the task and occupational distributions

Now that the demand for tasks and occupations have been presented in terms of employment, the wages paid to these tasks and occupations are examined in terms of their hourly wage levels by geography and year and how they evolved over time and between geographies in Table 2. The hourly wage levels across the ten provinces of Canada are higher in 1990 than for the four western provinces, which is itself larger than in the energy areas within those provinces for three of the four task groups. Wages paid to routine manual tasks were the only exception, which were slightly higher in the western region than in the other two geographical groups, though these differences are of little magnitude. The largest dollar differences in mean hourly wage between the geographical types appear at the top of the task distribution for non-routine cognitive tasks. By 2005, the hourly wage levels were much higher for both of the routine categories in the middle of the task distribution for energy areas than for the western region or the nation, and the non-routine task categories at the ends of the distribution had higher real wage levels for the regional and national geographies rather than in energy areas.

All of the task groups across all of the geographies experienced real wage losses during the stagnation period of the early 1990s, with the decrease being the largest for non-routine manual tasks. This particular decrease was more than twice the drop of all the other task groups combined in the energy areas, although there was virtually no decline in non-routine cognitive wages for this geographical type or at the regional level. For the energy set, the decrease for wages paid to routine manual tasks was also small. When the boom began over the late 1990s, the real wage changes were largest for the cognitive task groups at the national and regional levels, while the increases for the energy areas were the largest for non-routine tasks. When

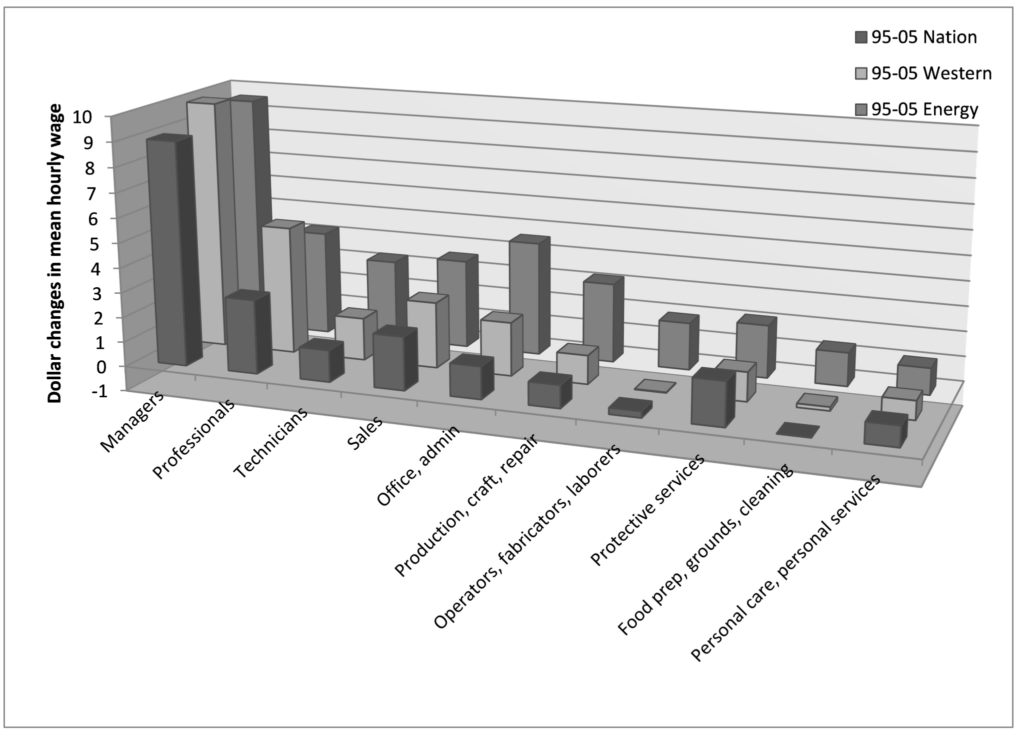
Table 2: Mean hourly wages and dollar changes by task

	Mean Hourly Wage				Δ Mean Hourly Wage		
Nation:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	29.50	28.52	30.88	33.50	-0.98	+2.36	+2.62
Routine cognitive	21.25	20.31	21.12	21.96	-0.94	+0.81	+0.84
Routine manual	21.19	20.38	20.32	20.98	-0.81	-0.06	+0.66
Non-routine manual	17.37	16.11	16.35	16.61	-1.26	+0.24	+0.26
Western:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	28.27	28.10	29.80	34.54	-0.17	+1.70	+4.74
Routine cognitive	20.90	20.14	20.80	22.50	-0.76	+0.66	+1.70
Routine manual	21.28	20.66	20.50	21.22	-0.62	-0.16	+0.72
Non-routine manual	16.81	15.78	16.03	16.26	-1.03	+0.25	+0.23
Energy:	1990	1995	2000	2005	90-95	95-00	00-05
Non-routine cognitive	25.09	25.07	25.80	31.33	-0.02	+0.73	+5.53
Routine cognitive	19.21	18.79	19.09	22.94	-0.42	+0.30	+3.85
Routine manual	21.02	20.89	21.02	23.30	-0.13	+0.13	+2.28
Non-routine manual	16.62	15.10	15.67	16.39	-1.52	+0.57	+0.72

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

the full boom hit during the early 2000s, all of the real wage increases across the entire task spectrum were largest in the energy areas by far. Specifically, the wage increase in energy areas for non-routine cognitive tasks was over 2 times higher than for the nation, routine cognitive wages were 4.5 times higher, routine manual wages were 3.5 times higher, and non-routine manual wages were over 2.5 times higher, all relative to the nation. So over time, the wages for the routine manual category in the energy areas remained the same until drastically increasing during the full energy boom. And, the relative wages gains between the energy areas and the other two geographies were the largest for the middle of the task distribution involving both routine task occupations.

Figure 3b: Wage Changes along the Occupational Distribution



Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

Figure 3b displays the wage changes across the ten occupational categories for the nation, region, and energy areas during the combined 10-year boom period. Beginning with the national changes in the foreground, the dollar changes are concentrated at the top of the occupational distribution for managers, with little relative wage change happening elsewhere in the distribution. The next highest wage changes were found for professionals, sales, and protective services. As the focus moves to Western Canada, the pattern of wage changes remains relatively the same, with a slightly higher wage gain for occupations in the top half of the distribution and a slightly lower wage gain for occupations in the lower half of the distribution. For the energy areas shown in the background, the wage gains at the top for managers remained similar to the nation, although these wages were slightly lower than for the western region, which is also true for professionals. But most importantly, the pattern for the wage gains in the energy areas is very different across the rest of the occupational distribution. Perhaps unsurprisingly, the largest relative wage increases for this geographical type are found in the routine task occupations of office and administration, production, craft, and repair, and operators, fabricators, and laborers. However, these relative wage gains are spread out even further along middle portion of the occupational distribution in these energy areas, from technicians to food preparation, grounds, and cleaning.

3.3 The routinization and manualization of tasks

Autor, Levy, and Murnane (2003) put forward a routinization hypothesis regarding the secular changes happening to the U.S. wage structure which were attributable to the adoption of technology. Their theory states that middle-skilled workers who perform routine tasks are continually being replaced by computers, due to their substitutability with this form of capital, while workers performing complicated non-routine tasks became highly demanded, due to their complementarity with this capital. Their empirical evidence also supports this hypothesis, as computerization is associated with the decreased routinization of tasks, resulting in a disappearing class of middle-skilled workers and an increased demand for college-educated workers. The cyclical change of the energy boom documented in the current paper is hypothesized to have the opposite effect as that of secular technological change, based on the demand-side evidence shown thus far, which would then lead to an increase in the routinization and manualization of tasks, at least in the energy areas containing these resources.

In order to empirically test this new hypothesis, the routine and manual employment share changes are regressed upon a treatment binary representing the energy areas using local labor markets for the variation.[9] This estimation will measure the

[9]This specification is similar to that of Autor and Dorn (2009, 2012), who were testing a different hypothesis. Their studies find that the contraction of routine middle skilled jobs in the local labor

differential growth in the routine or manual share of jobs within a local labor market between the energy and non-energy areas of the western region, as well as between the energy and non-energy areas of Canada as a whole. The following regression models measure this treatment effect for the dependent variable in percentage point and percentage terms, respectively:

$$\Delta ES_{ept} = \alpha + \beta \cdot Treat_{ep} + \gamma \cdot Prov_p + \varepsilon_{ept} \tag{2a}$$

$$\Delta ln(ES_{ept}) = \alpha + \beta \cdot Treat_{ep} + \gamma \cdot Prov_p + \varepsilon_{ept} \tag{2b}$$

where ΔES_{ept} is the change in the employment share of a particular group of workers, $Treat_{ep}$ is a binary indicator variable for energy areas, and $Prov_p$ represents the provincial fixed effects. The coefficient of interest, β, measures the difference in the average growth of the employment share between the treatment and comparison groups over a time period. At the moment, these regressions are stacked over the two boom periods, although this could also be analyzed separately for each period in a future analysis.

Whether these patterns between energy and non-energy regions do indeed differ and at what magnitude they differ by are measured statistically, with the results presented in Table 3. So, what is the magnitude of the boom effect on the routine and manual shares of employment? The routine employment share increased by 1.1 percentage points or by 1.9 percent due to the boom, averaged over each five-year boom period, with both estimates being statistically significant at the one percent level. The manual employment share increased by 0.7 percentage points or by 1.3 percent due to the boom, averaged over each five-year boom period, with both estimates being statistically significant at the five percent level. In addition, the set of comparison areas does not seem to matter for this estimation, as the effects are identical across all of the estimates using either geography.

The previous boom has now been attributed to both the routinization and manualization of tasks. But what does this mean for wages? In order to see how the routinization and manualization of tasks translate into wage differences paid to tasks, this relationship is now measured as the change in log wages on the change of the employment share, which is also interacted with the treatment binary. The following regression models address this issue in terms of percentage points and percentages, separately:

market has raised the share of people employed in the low skill non-routine sector, and the youngest cohort has experienced both a skill downgrade and an upgrade at the same time.

Table 3: Impact of the Boom on Routine and Manual Shares of Employment

	Routine Share (RS)			
	Nation		Western	
	ΔRS	ΔLogRS	ΔRS	ΔLogRS
Treat	0.011***	0.019***	0.011***	0.019***
	(0.004)	(0.006)	(0.004)	(0.006)
Prov	X	X	X	X
n	213	213	87	87

	Manual Share (MS)			
	Nation		Western	
	ΔMS	ΔLogMS	ΔMS	ΔLogMS
Treat	0.007**	0.013**	0.007**	0.013**
	(0.003)	(0.005)	(0.003)	(0.005)
Prov	X	X	X	X
n	213	213	87	87

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

$$\Delta ln(W_{ept}) = \alpha + \beta \cdot \Delta ES_{ept} + \delta \cdot \Delta ES_{ept} \cdot Treat_{ep} + \gamma \cdot Prov_p + \varepsilon_{ept} \tag{3a}$$

$$\Delta ln(W_{ept}) = \alpha + \beta \cdot \Delta ln(ES_{ept}) + \delta \cdot \Delta ln(ES_{ept}) \cdot Treat_{ep} + \gamma \cdot Prov_p + \varepsilon_{ept} \tag{3b}$$

where $\Delta ln(W)_{ept}$ is the change in the natural log of hourly wages, ΔES_{ept} is the change in the employment share of a particular group of workers, $Treat_{ep}$ an indicator variable for whether the local labor market is in the treatment group, and $Prov_p$ represents the provincial fixed effects. This estimation is once again stacked over both the early boom and full boom time periods.

The descriptive evidence showed that, while the wage increases in the energy areas were the largest for routine manual tasks, these wage gains were actually spread out

Table 4: Impact of Routinization and Manualization on Wages

	ΔLogWage			ΔLogWage	
	Nation	Western		Nation	Western
ΔRoutine	-0.182	-0.300	ΔLogRoutine	-0.110	-0.181
	(0.160)	(0.223)		(0.089)	(0.127)
ΔRoutine*Treat	1.051**	1.164**	ΔLogRoutine*Treat	0.607**	0.675**
	(0.004)	(0.544)		(0.307)	(0.326)
Prov	X	X		X	X
n	213	87		213	87
	ΔLogWage			ΔLogWage	
	Nation	Western		Nation	Western
ΔManual	0.129	-0.328	ΔLogManual	0.063	-0.190
	(0.180)	(0.359)		(0.097)	(0.200)
ΔManual*Treat	0.545	0.950	ΔLogManual*Treat	0.309	0.528
	(0.624)	(0.676)		(0.373)	(0.398)
Prov	X	X		X	X
n	213	87		213	87

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

even further along the occupational distribution. So, how does the boom translate into wage gains through the changes it makes to the employment shares associated with these type of tasks? A one percentage point increase in the routine employment share due to the boom is shown in Table 4 to have increased wages by 1.05 to 1.16 percent, while a one percent increase in the routine employment share led to a 0.60 to 0.68 percent increase in wages, with all of these estimates being statistically significant at the five percent level. A change in the manual employment share does not lead to any statistically significant changes in wages. So while the previous boom has been attributed to both the routinization and manualization of tasks, only the routinization of tasks has altered wages.

4 Skills supplied during the energy boom

4.1 The mapping of skills to tasks

Now that the effects of the positive labor demand shock of the energy boom have been identified along the task and occupational distributions, this section begins by seeing how skills match up to those demanded tasks and occupations. The employment and wage changes on the supply side are predicted to move towards the skill groups that are the best matches for those demanded tasks. Mimicking the skill-biased secular change literature, this skill-biased energy boom hypothesis is now investigated within the current study.[10] The distribution of skills is now examined on the supply side of the labor market using a similar methodology to what was followed for the task and occupational distributions on the demand side. Once again, the evidence is a combination of descriptive analysis, used to represent the broad changes, and regression analysis, used to determine the magnitude and statistical significance of these relationships.

Like the secular change literature, education is used to represent the skills of the workforce. This study categorizes workers into six different skill groups in order to represent the distribution of skills that are supplied to the labor market, all based on their highest education credential received. The first group of individuals contains those with less than a high school (i.e. secondary school) graduation certificate. The second group contains those with a high school graduation certificate. The third group contains those who achieved a trades certificate or diploma, which includes registered apprenticeship certificates. The fourth education group contains those who earned non-university and university certificates or diplomas below the bachelor's degree. The fifth group contains those with a bachelor's degree as their highest educated credential achieved. The sixth group contains all of the post-graduates, including those with a university certificate above a bachelor's degree, a degree in medicine, dentistry, veterinary medicine, or optometry, a Master's degree, or a doctorate degree.

The skill categories that are used in this paper are mostly in-line with the previous literature, with two notable exceptions. First, instead of sorting individuals into education groups based on their years of schooling, the skill categorization of this study is defined using the highest degree, certificate, or diploma achieved. This difference is due to the availability of these variables in the Canadian data over time, as compared with what is typically available in the U.S. data. The variable for the

[10]Skill-bias generally refers to a labor demand change causing a need for one type of skill group over another.

highest education credential is kept consistent across the four waves of Census data, while the total years of schooling variable is only available in the first three of the four Census waves. Second, the literature typically uses five skill groups or fewer to represent the skill distribution rather than six. In the current study, individuals who graduated with trades and apprenticeship certificates are separately identified from those with some college or university but with less than a bachelor's degree, as this group presumably plays a relatively important role during an energy boom.

That said, the six skill groups of the current paper can easily be represented by fewer categories without requiring further calculation. In order to compare the current results to five skill groups, the two middle-skill categories can roughly be averaged together. To compare the results to those generated by three skill groups, the six groups can be aggregated into three broad categories: the low-skilled (high-school graduates and those with less education), the middle or semi-skilled (trades graduates and those with less than a four-year degree), and the high-skilled (those with a bachelor's degree or higher). And to compare these results to the two-group categorization of low-skilled and high-skilled in the literature, one only needs to compare the results for high school graduates to that of 4-year university graduates.

The overlap between the distributions of task and skill are presented in Table 5 for all three of the geographical types, but only for the pre-boom year of 1995. In this table, the tasks shares for each row of an education category add up to one hundred percent of all of its graduates. Looking within each column designating a task group, the share employed in non-routine cognitive tasks increases when moving up the skill distribution, while the share employed in non-routine manual tasks decreases when moving up the skill distribution. Therefore, managers, professionals, and technicians are considered to be the occupations that require the highest level of education, while the occupations of protective services, food preparation, grounds, and cleaning, and personal care and personal services require the least amount of education. The middle two routine task groups have more of a mix of graduates across the varying education groups.

How much do the needs of firms, in terms of the tasks demanded due to the energy boom, match up with the readiness of workers, in terms of their skills supplied to the market? Given that routine manual tasks were heavily favored in the energy areas during the energy boom, it would seem that these needs are being met mainly by workers from the lower and middle portions of the skill distribution. While over half of the less than high school graduates and trades and apprenticeship graduates are employed in routine manual tasks at the regional and national levels, roughly two-thirds of trades and apprenticeship graduates work in these tasks in energy areas, along with slightly less than two-thirds of less than high school graduates, slightly

Table 5: Task shares by skill group in pre-boom year of 1995

Task Share by Skill	Non-routine cognitive	Routine cognitive	Routine manual	Non-routine manual
Nation:				
< High school graduate	14.08	14.16	56.63	15.11
High school graduate	25.18	22.29	38.38	14.13
Trades and apprenticeships	20.89	10.20	58.65	10.23
< 4-year university graduate	47.71	18.00	24.04	10.23
4-year university graduate	74.61	15.65	5.54	4.18
> 4-year university graduate	89.75	6.41	2.27	1.55
Western:				
< High school graduate	16.15	15.05	54.41	14.37
High school graduate	26.28	22.12	36.48	15.10
Trades and apprenticeships	21.95	10.05	58.38	9.60
< 4-year university graduate	48.17	17.16	24.67	9.98
4-year university graduate	74.10	14.58	6.07	5.23
> 4-year university graduate	90.70	5.58	2.07	1.63
Energy:				
< High school graduate	15.87	10.77	62.23	11.10
High school graduate	23.53	15.74	48.37	12.33
Trades and apprenticeships	18.85	8.07	65.36	7.71
< 4-year university graduate	43.08	12.52	34.78	9.59
4-year university graduate	79.36	7.84	8.06	4.73
> 4-year university graduate	93.05	3.51	2.18	1.25

Notes: Author's calculations of 1996 Canadian Census individual-level data.

less than half of high school graduates, and slightly more than a third of less than 4-year university graduates. Therefore, these are the particular skill categories where the increased demand for routine manual tasks may be met.

4.2 The changing returns to skills and skill premia

The local labor supply is not assumed to be shocked by the energy boom like that of local labor demand. Instead, local labor supply may be adjusting to that local labor demand shock over time, as the needs of firms on the demand-side become known and individuals have time to develop the skills to fit the tasks most demanded. Therefore, any labor supply adjustment should not be seen during the initial labor demand shock during the early boom period, but it could be taking place during the full boom period after the initial shock occurs. Now that the distributional overlap of tasks and skills has been documented, the changing returns to these skills over the various time periods and the skill premia between each of the skill groups can be examined.

The mean hourly wages paid to each of these education credentials by geography and year, as well as their changes over each time period, are presented in Table 6. The real wage levels in 1990 are the highest for all skill groups at the national level, followed by the western region, and then the energy areas. The only exception is for trades and apprenticeship graduates, who have hourly wages slightly higher in the western region than for the energy areas or at the national level. That said, these differences are not at all large between the region and the nation, but do differ quite a bit between these two geographies and the energy areas, especially when moving up the educational distribution. By 2005, these trends reversed, as the mean hourly wages were higher in the energy areas than for Canada or Western Canada for all but the high-skilled educational groups.

During the 90-95 time period, the dollar changes in real hourly wages appear to uniformly decrease at the national level, while these decreases are larger towards the middle of the distribution for the western region and energy areas. These relatively universal decreases should not be surprising, because Canadian GDP also decreased by about 3 percent during this time period, so it is merely a reflection of this economic recession of the early 1990s. The only exception is for more than 4-year university graduates, who actually experienced wage increases in Canada and in the energy areas during this time. The early boom of the 95-00 time period tends to favor wage increases at the high end of the skill distribution over the low and middle portions, especially for the western region and the nation. These increases were strictly monotonic for only the western region. That said, the largest wage gains

Table 6: Mean hourly wages and dollar changes by education

	Mean Hourly Wage				Δ Mean Hourly Wage		
Nation:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	19.68	18.52	18.48	18.40	-1.16	-0.04	-0.08
High school graduate	21.37	20.08	20.28	20.68	-1.29	+0.20	+0.40
Trades and apprenticeships	23.14	21.89	22.48	22.74	-1.25	+0.59	+0.26
< 4-year university graduate	25.13	23.60	24.77	25.57	-1.53	+1.17	+0.80
4-year university graduate	30.57	28.77	32.63	34.43	-1.80	+3.86	+1.80
> 4-year university graduate	35.99	34.26	37.78	39.29	+1.73	+3.52	+1.51
Western:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	19.53	18.91	18.77	19.26	-0.62	-0.14	+0.49
High school graduate	20.68	19.82	19.90	20.65	-0.86	+0.08	+0.75
Trades and apprenticeships	23.35	22.44	23.06	24.60	-0.91	+0.62	+1.54
< 4-year university graduate	24.69	23.47	24.57	26.36	-1.22	+1.10	+1.79
4-year university graduate	29.46	28.35	31.01	35.35	-1.11	+2.66	+4.34
> 4-year university graduate	34.14	33.25	36.48	40.15	-0.89	+3.23	+3.67
Energy:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	18.50	18.34	18.78	20.90	-0.16	+0.44	+2.12
High school graduate	19.62	19.35	19.03	21.83	-0.27	-0.32	+2.80
Trades and apprenticeships	22.93	22.19	23.31	25.95	-0.74	+1.12	+2.64
< 4-year university graduate	23.59	22.49	23.04	26.63	-1.10	+0.55	+3.59
4-year university graduate	27.66	26.54	27.08	33.10	-1.12	+0.54	+6.02
> 4-year university graduate	31.19	31.72	33.58	37.00	+0.53	+1.86	+3.42

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

in dollar terms for the energy areas were for more than 4-year university graduates followed by trades and apprenticeship graduates. Similar trends continue for the national and western region during the full boom of the 00-05 time period, with larger increases at all skill levels in the western region. This trend for the full boom is quite different for the energy areas though, with more than two-dollar increases in the wage rates for the lower half of the skill distribution and more than three-dollar increases in the wage rates for the upper half of the skill distribution.

While the routine manual tasks are consistently demanded over both of the boom periods in the energy areas, with the best match for these tasks being trades and apprenticeship and less than high school graduates, these two skill groups did not experience significantly large hourly wage increases until the full boom arrived. Comparing these two skill groups between geographical types, the early boom wage gains for less than high school graduates are only positive in the energy areas, and are less than twice as high for trades and apprenticeship graduates as compared to the regional level. Most interestingly though is that, during the full boom period, the wage gains were more than four times as high in energy areas over the regional level for less than high school graduates. For trades and apprenticeship graduates, these wage gains were more than ten times higher than the gains at the national level. That said, high school graduates also realized differential wage gains in energy areas, with three to seven times the wage gains of the other two geographies. Furthermore, less than 4-year university graduates made two to more than four times more in wages per hour in the energy areas as well.

Another way to view these relative wage gains and losses is through the relationships between skill groups. These hourly wage ratios and their percentage changes are presented by skill premium in Table 7. Instead of adopting the conventional approach of calculating the wage premium for university graduates in relation to high school graduates (i.e. high-skilled to low-skilled), the skill premium is calculated for every skill group in relation to the one before it, moving from the bottom to the top of the skill distribution. Given the evidence presented within the previous two tables, however, the main focus is on what is happening between the groups in the lower two-thirds of this distribution. In 1990, the hourly wage premium was exactly the same for all of the low-skilled and middle-skilled comparisons at the national level, with an 8 percent return to each credential. That said, the premium paid to trades and apprenticeship graduates was markedly higher in the western region, and even higher still in the energy areas. At the same time, the premium paid to high school graduates were both equally lower in these two areas as compared to the nation, while the premium paid to less than 4-year university graduates was lower in the western region, and then even lower still in the energy areas. The wage premia for

Table 7: Hourly wage ratio and ratio changes by skill premium

	Hourly Wage Ratio				Δ Hourly Wage Ratio		
Nation:	1990	1995	2000	2005	90-95	95-00	00-05
HSG to < HSG	1.086	1.084	1.097	1.123	-	+	+
TAG to HSG	1.082	1.089	1.108	1.099	+	+	-
< UNG to TAG	1.086	1.078	1.101	1.124	-	+	+
UNG to < UNG	1.216	1.219	1.317	1.346	+	+	+
> UNG to UNG	1.177	1.190	1.157	1.140	+	-	-
Western:	1990	1995	2000	2005	90-95	95-00	00-05
HSG to < HSG	1.059	1.048	1.059	1.072	-	+	+
TAG to HSG	1.128	1.131	1.159	1.191	+	+	+
< UNG to TAG	1.057	1.046	1.065	1.071	-	+	+
UNG to < UNG	1.193	1.207	1.261	1.341	+	+	+
> UNG to UNG	1.158	1.172	1.176	1.135	+	+	-
Energy:	1990	1995	2000	2005	90-95	95-00	00-05
HSG to < HSG	1.059	1.054	1.013	1.044	-	-	+
TAG to HSG	1.168	1.146	1.224	1.188	-	+	-
< UNG to TAG	1.028	1.013	0.988	1.025	-	-	+
UNG to < UNG	1.172	1.180	1.175	1.243	+	-	+
> UNG to UNG	1.127	1.194	1.240	1.117	+	+	-

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data. HSG is high school graduates, TAG is trade and apprenticeship graduates, and UNG is 4-year university graduates.

the high-skilled groups were also higher for the nation, than for the western regions, and even more so than in the energy areas.

Between 1990 and 1995, these wage premia all slightly decreased, with the exception of the trades and apprenticeship premium slightly increasing at the regional and national levels. The high-skilled groups experienced an increase in their premia across all of the geographies. When the early boom came between 1995 and 2000, all of the premia rose at the regional level, all but that of more than 4-year university graduates rose at the national level, and only the trades and apprenticeship and the more than 4-year university premia rose in the energy areas. During the full boom between 2000 and 2005, the premium at the very top of the skill distribution decreased regardless of geography, while increasing for all but trades and apprenticeship graduates at the national level and in energy areas. Although in 2000 the trades and apprenticeship premium was the highest by far in the energy areas, this decrease between 2000 and 2005 put it almost equal to that of the western region by 2005.

4.3 The employment composition of skills

With the identification of the demanded tasks due to an energy boom, the mapping of these demand tasks to skills, and the movements in the wages and wage premiums paid to skills, there are only two more types of analysis to carry out: the changes to the employment composition of skills and the measurement of the substitutability of skills. Just as the concentration of employment was shown over the distribution of tasks on the demand side of the analysis, that same approach is now applied to the distribution of skills on the supply side. If the observed employment changes for skills are not consistent with the observed wage changes for these groups over time, the existence and severity of the demand for routine manual tasks will then depend on the substitutability between skill groups in the event of any skill-bias (i.e. a situation where one skill group is needed more than another).

The employment shares by education group and their percentage point changes over time are shown in Table 8. In 1990, the employment shares of those with less than a high school diploma and with trades and apprenticeship certificates are much higher in the energy areas than in the other two geographies. That said, the shares of high school graduates and all other skill groups are markedly higher in the nation and the western region than in energy areas. While the relative level of high school graduates is somewhat lower in energy areas in 1990, it grows over time for all three geographical groups, and ends up slightly higher in energy areas by 2005. This increase in the share of high school graduates is largest during the 2000-05 period, and

Table 8: Employment shares and percentage point changes by skill

	Employment Share				Δ Employment Share		
Nation:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	25.97	21.72	19.83	12.42	-4.25	-1.89	-7.41
High school graduate	22.64	22.49	22.66	24.25	-0.15	+0.17	+1.59
Trades and apprenticeships	17.59	16.49	16.93	16.03	-1.10	+0.44	-0.90
< 4-year university graduate	15.54	18.55	19.20	23.89	+3.01	+0.65	+4.69
4-year university graduate	11.18	12.90	13.50	14.60	+1.72	+0.60	+1.10
> 4-year university graduate	7.05	7.82	7.85	8.78	+0.77	+0.03	+0.93
Western:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	25.93	22.60	21.11	13.14	-3.33	-1.49	-7.97
High school graduate	21.83	21.33	21.40	26.31	-0.50	+0.07	+4.91
Trades and apprenticeships	20.09	19.30	19.71	16.88	-0.79	+0.41	-2.83
< 4-year university graduate	14.64	17.14	17.56	22.09	+2.50	+0.42	+4.53
4-year university graduate	11.08	12.50	13.08	13.80	+1.42	+0.58	+0.72
> 4-year university graduate	6.40	7.09	7.12	7.75	+0.69	+0.03	+0.63
Energy:	1990	1995	2000	2005	90-95	95-00	00-05
< High school graduate	31.13	28.27	27.07	18.95	-2.86	-1.20	-8.12
High school graduate	19.65	19.75	20.52	27.65	+0.10	+0.77	+7.13
Trades and apprenticeships	25.70	25.61	26.66	22.76	-0.09	+1.05	-3.90
< 4-year university graduate	12.50	14.72	14.78	20.09	+2.22	+0.06	+5.31
4-year university graduate	7.28	7.71	7.46	7.15	+0.43	-0.25	-0.31
> 4-year university graduate	3.70	3.91	3.49	3.37	+0.21	-0.42	-0.12

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data.

it is quite dramatic, especially in the western region and energy areas. The significant decreases in less than high school graduates and in trades and apprenticeship graduates during this later time period must be correlated with this significant increase in high school graduates, with many more individuals graduating high school during this time that might not have done so historically, or individuals possibly dropping out of trades and apprenticeship programs to instead find employment as high school graduates. Given the wage evidence for energy areas in the full boom, this latter possibility would not be surprising.

Another important point is that the employment changes are drastically different between the two boom periods in the lower and middle portions of the skills distribution, even though the demand for routine manual tasks is consistent. In the energy-rich areas, the largest increase in employment share is for trades and apprenticeship graduates in the early boom, while this group experiences a significant decrease in the full boom. Given that the two skill groups that best fit the demanded routine manual tasks are drastically decreasing in the full boom, imperfect substitution may be happening between these skill groups in the lower and middle portions of the distribution. This leads to the measurement in the last section of the analysis.

4.4 Imperfect substitution between skill groups

The estimation of the elasticity of substitution between two groups of workers is mainly found within the immigration literature, where the substitutability between natives and immigrants is estimated across various education levels (for examples, see Borjas, Grogger, and Hanson, 2008, 2012; Card, 2009). The following regression model is run to estimate the relationship between the wage premium on the relative supply for several pairs of skill groups:

$$ln\left[\frac{W_{skill1}}{W_{skill2}}\right] = \alpha + \beta \cdot ln\left[\frac{S_{skill1}}{S_{skill2}}\right] + \gamma \cdot Prov_p + \varepsilon_{ept} \tag{4}$$

where the dependent variable is the natural log of the wage premium between two skill groups, the main independent variable is the natural log of the relative supply between these two groups, and provincial fixed effects are additionally controlled for. Note that this estimation is currently done at the national level using all available local labor market variation over all three time periods, while a future iteration of this study might employ a method that takes the energy areas into account along with their differences from non-energy areas and their changes over time.

The regression coefficients produced from equation (4) are presented in the first column of Table 9. If these estimates are found to be statistically insignificant,

Table 9: Hourly wage ratio and ratio changes by skill premium

Nation:	Regression Coefficient	Implied Elasticity of Substitution
HSG to < HSG	0.078***	12.82
	(0.012)	
TAG to HSG	-0.021***	47.62
	(0.009)	
< UNG to TAG	0.033***	30.30
	(0.009)	
UNG to < UNG	0.083***	12.04
	(0.014)	
> UNG to UNG	0.091***	10.98
	(0.010)	
Prov	X	.
n	292	.

Notes: Author's calculations of 1991, 1996, 2001, and 2006 Canadian Census individual-level data. HSG is high school graduates, TAG is trade and apprenticeship graduates, and UNG is 4-year university graduates.

then it can be concluded that the two skill groups are perfect substitutes for one another. This is not the case for any of the pairs of skill groups, however, as all of the estimated coefficients are statistically significant at the one percent level. That said, only one coefficient yields the expected negative sign, while all of the other coefficients are positive. The estimated negative and statistically significant coefficient implies that high school graduates are serving as imperfect substitutes for trades and apprenticeship graduates, in order to possibly help fill the demand for workers to perform routine manual tasks during the energy boom. The rest of the statistically significant and positive coefficients may imply that something is wrong with the specification, although these problems are not unique to this paper (again, see Borjas, Grogger, and Hanson, 2008, 2012; Card, 2009).

If we choose to ignore the signs, however, the implied elasticity of substitution is found by dividing this estimated coefficient by one. These results are shown in the second column of Table 9. The relatively small magnitudes for the coefficients between trades and apprenticeship graduates and high school graduates, and between less than 4-year university graduates and trades and apprenticeship graduates, lead to relative large implied elasticities of substitution between those skill groups. This is perhaps not that surprising given that the trades and apprenticeship graduates are usually mixed into some combination of both of those skill groups. However, within the context of the current paper, there findings are very important. If the implied elasticities of substitution are correct, and the adjacent skill groups are highly substitutable for trades and apprenticeship graduates, then this would be a good reason why their relative wages rose by nearly as much as one another during the full boom period, when the supply of trades and apprenticeship graduates was in decline, even though they seemed best fit for the tasks in demand. If a new energy boom were to begin today, this substitutability between skill groups may also help accommodate such a sudden increase in labor demand.

Less than high school graduates are shown to be poor substitutes for high school graduates, as shown by the relatively low implied elasticity of substitution, even though they were the second best fit for the jobs in demand according to the mapping of tasks to skills. Therefore, their wage gains came from their fit during the full boom rather than their substitutability with other skill groups. Less than university graduates and university graduates, as well as university graduates and more than university graduates, are also not that substitutable for one another.

Note that in addition to substitutability happening on the supply side, the task-content that is demanded within the routine manual tasks may be changing from the early boom to the full boom. This could be masked in the way it is shown in this paper as the employment changes were only shown by occupational groups over the full boom period. Given the large sector spillovers identified for this region during this previous energy boom in Marchand (2012), it could be that the sectors being spilled into are needing other types of skills than what the directly impacted energy sector needs as the boom continues on over time.

5 Conclusion

While secular changes to the wage structure have pervaded the literature, such as those related to the rise of technology, cyclical changes to the wage structure have been largely ignored. Recognizing this gap, the current paper measures the impacts of a recent energy boom on the local labor markets of Canada. It uses a sample of employed individuals from the Census of Population over three intercensal time periods representing the gradual stages of the energy boom process. Three different sets of local labor markets are used to establish the sources of the employment and wage changes as either cyclical or secular, with the cyclical changes attributed to the energy areas and the secular changes attributed to the non-energy areas. Ten aggregate occupational groups, four task groups, and six skill groups help to further refine the changes of interest.

The evidence presented in this paper comes from a combination of descriptive analysis, used to represent the broad changes happening to employment and wages due to the energy boom, and regression analysis, used to more precisely determine the magnitude of these changes attributable to the boom. The analysis of the paper begins by looking at changes across the task and occupational distributions on the demand-side of the labor market. First, the employment changes are documented across the geographical groups and over time for tasks and occupations. Then, the wages changes are examined across these same distributions. Lastly, the impact of the energy boom is measured upon various employment share changes, and the effects of these employment share changes are then measured upon wages. The supply-side analysis first identifies the overlap between the task distribution and the skill distribution. Then, the changes in wages and wage premiums are documented across the skill distribution. Lastly, the employment changes across this distribution are documented and the substitutability between skill groups is measured.

The employment share changes in the energy areas during the boom are shown to favor the lower middle portion of the task distribution, increasing the demand for routine and manual tasks and reducing the demand for non-routine and cognitive tasks. These huge increases in the demand for routine manual tasks in the energy areas are consistent over the early boom and full boom periods. Both of the occupations performing routine manual tasks experience large relative increases, with the increase for production, craft, and repair being of somewhat larger magnitude than for the region and nation and the increase for operators, fabricators, and laborers being the most drastic increase by comparison. Over time, the wages for the routine manual category in the energy areas remained the same until drastically increasing during the full energy boom. Furthermore, the relative wages gains between the energy areas and the other two geographies were the largest for the middle of the task distribution involving both routine task occupations. These relative wage gains are spread out even further along middle portion of the occupational distribution in these energy areas, from technicians to food preparation, grounds, and cleaning. The previous boom has now been attributed to both the routinization and manualization of tasks, but only the routinization of tasks has altered wages.

The overlap of the occupational and educational distributions reveals that these lower middle occupations appeared to be concentrated primarily within the low to middle education groups, namely for trades and apprenticeship graduates and less than high school graduates. These two skill groups do not experience significantly large hourly wage increases until the full boom arrives, however, when the neighboring skill groups also share in the gains. The wage premium was much higher for trades and apprenticeship graduates in the energy areas, while the premia paid to the neighboring credentials were very small. The employment changes are drastically different between the two boom periods in the lower and middle portions of the skills distribution, even though the demand for routine manual tasks is consistent. High school graduates and less than 4-year university graduates may be imperfectly substituting for trades and apprenticeship graduates.

The evidence from this large and localized cyclical change vastly differs from the findings of the secular change literature in several important ways. First, energy booms are found to lead to the routinization and manualization of tasks, with the change in labor demand oriented towards the lower middle portion of the occupational distribution. This is the exact opposite of the polarization found in the secular change in developed countries in recent years, as routinization is seen as being replaced by technology and is therefore in less relative demand. Second, the demanded skills that match up with the demanded tasks are found in the lower and middle portions of the skill distribution, rather than the documented secular changes of polarization towards the tails of that distribution. Third, while an energy boom is cyclical in nature, the magnitude of its effects may be large enough to offset any simultaneously-occurring secular changes.

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Table A1: Economic regions within the energy treatment group

ER No.	Province	Name	1995 Fraction	2005 Fraction
4880	AB	Wood Buffalo/Cold Lake	0.509	0.462
4840	AB	Banff/Jasper/Rocky Mountain House	0.245	0.230
5980	BC	Northeast	0.197	0.206
4870	AB	Athabasca/Grande Prairie/Peace River	0.191	0.245
4820	AB	Camrose/Drumheller	0.181	0.255
4850	AB	Red Deer	0.166	0.250
5940	BC	Kootenay	0.096	0.108
4810	AB	Lethbridge/Medicine Hat	0.077	0.170
4720	SK	Swift Current/Moose Jaw	0.066	0.135
4750	SK	Prince Albert	0.054	0.096

Notes: Author's calculations based on 1996 Census wave data using the 2006 Census wave division boundaries. The decision rule was based on having more than five percent of total earnings from energy extraction in the base year of 1995. One economic region was omitted for being a major city, which was ER No. 4830 for Calgary, AB.