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Michael Dolega, David Dupuis, and Lise Pichette

Canadian Economic Analysis Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
mdolega@bankofcanada.ca
daviddupuis@bankofcanada.ca
lpichette@bankofcanada.ca

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Abstract

In recent years, the Canadian economy has been affected by strong movements in relative prices brought about by the surging costs of energy and non-energy commodities, with significant implications for the terms of trade, the exchange rate, and the allocation of resources across Canadian sectors and regions. While the energy and mining industries have benefited from these movements, the pressure on the manufacturing sector has intensified, since many firms in this sector were already dealing with growing competition from low-cost economies such as China. The adjustments undertaken within the Canadian economy are readily noticeable through investment decisions, as well as through production and employment reallocation. Using vector autoregressive techniques, the authors examine how an appreciation in commodity prices and the subsequent reallocation of resources across sectors will affect hours worked and output growth and, ultimately, aggregate and sectoral labour productivity growth in Canada. Results suggest that the impact of a positive relative price shock will – in the adjustment process – lower productivity growth in the primary and the non-tradable sectors, and increase it somewhat in the manufacturing sector. The overall impact appears to be slightly negative on aggregate labour productivity growth, but this effect is only temporary.

JEL classification: E23, E24, O47
Bank classification: Recent economic and financial developments; Productivity; Labour markets

Résumé

Ces dernières années, l’économie canadienne a subi les effets de fortes variations des prix relatifs provoquées par l’envolée des cours des produits de base énergétiques et non énergétiques, lesquelles ont eu d’importantes conséquences sur les termes de l’échange, le taux de change et la répartition des ressources entre les régions et les secteurs économiques canadiens. Si ces variations ont profité aux industries énergétique et minière, elles ont intensifié les pressions qui pesaient sur le secteur manufacturier, car de nombreux fabricants faisaient déjà face à la concurrence grandissante d’économies aux coûts de production peu élevés comme la Chine. Les efforts d’ajustement engagés dans l’économie canadienne sont nettement perceptibles dans les décisions d’investissement et la redistribution de la production et de l’emploi. Les auteurs font appel à un vecteur autorégressif pour étudier quelles répercussions un renchérissement des produits de base et la redistribution intersectorielle des ressources qui s’ensuivrait auraient sur les heures travaillées et l’augmentation de la production, puis, en dernier ressort, sur la croissance

de la productivité globale et sectorielle du travail au Canada. Leurs résultats portent à croire qu'un choc positif des prix relatifs freinerait, au fil des ajustements nécessités, la croissance de la productivité dans le secteur primaire et celui des biens non échangeables et lui imprimerait un modeste élan dans le secteur manufacturier. Un tel choc aurait un effet net légèrement négatif, quoique temporaire, sur la croissance de la productivité globale du travail.

Classification JEL : E23, E24, O47
Classification de la Banque : Évolution économique et financière récente; Productivité; Marchés du travail

1 Introduction

In recent years, Canadian relative prices have experienced profound changes as commodity prices have soared relative to the prices of both manufactured goods in international markets and services in domestic economies. At the core of this price realignment is the rise in energy and non-energy commodity prices, propelled by the robustness of growth in the global economy, increased income and per capita demand from emerging-market countries such as China, the apparent bottlenecks in supply (particularly in the energy market segment), and increased geopolitical uncertainty. In response to these important price movements, Canada's terms of trade – the ratio of the price of exports of goods and services to the price of imports of goods and services – have improved considerably, which is of benefit to Canadians, since Canada is a substantial net commodity exporter.

A further outcome has been a rapid and substantial appreciation of the Canadian dollar against the U.S. dollar.[1] After reaching its lowest level in January 2002, the Canadian dollar had appreciated 58 per cent by mid-2008. This exchange rate appreciation, combined with commodity price increases and terms-of-trade improvements, has led to major adjustments in the Canadian economy. While the energy and mining industries have benefited from these commodity price movements, pressures on the manufacturing sector have intensified substantially. Many manufacturers were already dealing with growing competition from low-cost producers such as China. The adjustments undertaken within the Canadian economy are now readily noticeable through investment decisions and shifts in employment (and hours worked), with associated impacts on sectoral and aggregate output and productivity growth.

In this paper, we examine how the relative price movements, described above as an important appreciation in commodity prices, and the associated reallocation of resources across sectors will affect labour productivity in Canada. The monetary authority in Canada pays close attention to trend productivity growth, which is a key element of potential output growth and is therefore instrumental in monetary policy decisions (see, for example, Duguay 2006). Since various economic sectors may be affected differently by relative price movements – some adversely and others positively – the effect on labour productivity growth will likely vary between sectors, depending on the adjustments. In such an environment, examining productivity by sector is important to better understand the aggregate.

This paper is organized as follows. In the next section we describe a simple 3-sector model, since it represents a good starting point to analyze the current adjustments in the Canadian economy. We also describe the ongoing adjustment process and introduce some insights regarding sectoral and aggregate productivity. In section 3, we review recent output and employment flows, and

1. The Canadian dollar did indeed appreciate against many currencies over the 2003–08 period.

compare them to the predictions of the 3-sector model described in section 2. Section 4 briefly describes the proposed empirical approach and presents the results. Some concluding remarks follow in section 5.

2 Economic Adjustments to a Commodity Price Increase

A natural approach when investigating the reallocation of resources following an important commodity price movement is to adopt a 3-sector model that segments the economy into two tradable sectors – resource and manufacturing – and a non-tradable sector.[2] This type of theoretical model has been put forth by the seminal work of Corden and Neary (1982) and Corden (1984), among others, to analyze the potential effects of a boom in the resource sector on employment, wages, and output.[3]

Considering the fact that Canada is a small open economy, we assume in our analysis that the tradable sectors are price-takers on the world market. In the short run, output in each sector will be produced by sector-specific capital and generic labour, with the latter being mobile between all three sectors, equalizing wages within the economy. In such a framework, a rise in commodity prices is expected to cause resource firms to expand production and employment in the short term and to increase capacity in the longer term, through investment. The resulting increase in labour demand pushes up wages in the natural resource sector. In an economy like Canada's, which is a net exporter of commodities, the accompanying gains in terms of trade boost the real gross national income, final domestic demand, and the value of the currency. The currency appreciation facilitates both the transfer of productive resources to the commodity-producing sector and the buildup of capacity in the non-tradable sector to accommodate the expansion of domestic demand. It does so by redirecting this demand towards imported goods and services, by discouraging the production of manufactured goods for exports, and by reducing the price of imported machinery and equipment relative to labour. As a result of these adjustments, the manufacturing sector contracts, and the non-tradable sector tends to expand provided that it remains relatively insulated from the ongoing wage pressures in the resource sector. As we will show, this is largely the scenario that has unfolded in Canada in recent years.

The above analysis permits a better grasp of potential movements in output and employment following a boom in the resource sector. However, it does not consider how the expected

2. From a reallocation point of view, we define the non-tradable sector as Construction (North American Industry Classification System, or NAICS, 23); Wholesale and Retail Trade (NAICS 41, 44-45); Transportation and Warehousing (NAICS 48-49); Information and Cultural Industries (NAICS 51); Finance, Insurance and Real Estate (NAICS 52-53); Professional, Scientific and Technical Services (NAICS 54); Administrative and Support, Waste Management and Remediation Services (NAICS 56); Arts, Entertainment and Recreation (NAICS 71); Accommodation and Food Services (NAICS 72); and Other Services (except Public Administration) (NAICS 81). We exclude from the non-tradable sector the following subindustries: Utilities (NAICS 22), Educational Services (NAICS 61), Health Care and Social Assistance (NAICS 62), and Public Administration (NAICS 91), since they are government-controlled sectors, which may respond to economic incentives in an idiosyncratic manner.
3. As advocated by Corden and Neary (1982), a boom can be brought about in one of the trading sectors by a one-time technical improvement, a windfall discovery of new resources, or a rise in the price of the sector's particular product on the world market.

movements could affect labour productivity. Three types of potential effects arising from the economic adjustments are considered in the literature: (i) an accounting effect, (ii) a cost-of-adjustment effect, and (iii) an incentive effect.

First, in the case of the accounting effect, the aggregate productivity level might change following labour reallocation, because workers move between sectors with different productivity levels. In other words, some of the movements in aggregate labour productivity, measured as a weighted average of sectoral productivity, simply result from a change in the sectoral composition. For example, as implied by Faruqui et al. (2003), aggregate productivity growth might increase if workers are moving towards high-productivity-level sectors even if productivity growth is negative for all sectors. Given the sectors' capital-labour ratio position in Canada – productivity is highest in the resource sector, followed by the manufacturing and the non-tradable sectors – the expected expansion of the resource sector should boost productivity levels in Canada, while the decline in manufacturing, in part to the benefit of the non-tradable sector, should lower it. Recent evidence suggests, however, that the shares of the extraction and the manufacturing sectors to GDP have been falling in favour of the non-tradable sector.[4] The net accounting effect would therefore suggest a decline in productivity levels over the adjustment period.

Second, when an economy is reallocating resources following an important change in relative prices, there appears to be a consensus in the literature that adjustment costs reduce the pace of efficiency gains. Sectoral reallocation leads to some disruption of regular work in both declining and expanding sectors, with negative effects on productivity.[5] In the declining sector, the remaining workers have to take over unfamiliar tasks when colleagues leave, and the work has to be reorganized. In the expanding sector, new workers have to be trained and the productivity of experienced workers will decline as they contribute to the integration of new employees. Learning by doing or by training will be compromised in the adjustment period, which may permanently lower income per capita.[6] However, these costs are very difficult to measure, and there is no clear indication as to how long it takes to reach an efficient pace of production after a period of resource reallocation.

Finally, a relative price change, such as that recently experienced in Canada, is more than likely to alter economic incentives if it is deemed to be persistent. One way this incentive effect works is by raising the capital-labour ratio, since the currency appreciation that accompanies the commodity price increase lowers the costs of imported machinery and equipment relative to labour. Another way the incentive effect works, as suggested by Harris (2001), is through intensified competitive pressures, particularly in the manufacturing sector, in view of its high

4. As a share of business sector GDP, the extraction industries fell from 6 per cent in 1997 to 5 per cent in 2006, and the manufacturing sector contracted from 24 to 21 per cent, while the non-tradable share increased from 70 to close to 74 per cent.
5. See, for example, Hamermesh and Pfann (1996); Gaisford and Leger (2000); Bernstein, Mamuneas, and Pashardes (2004).
6. See, for example, van Wijnbergen (1984); Gylfason, Herbertsson, and Zoega (1999).

external trade exposure. These pressures could lead to the closure of the least-efficient plants and to the exit of the least-efficient firms, improvements in technology, changes in work practices, and other productivity-enhancing adjustments. With all these new incentives in place, there is a presumption that a sustained real exchange rate appreciation could have positive consequences for long-term productivity growth. It may, however, still be too early to appreciate the full benefits of this incentive channel to the Canadian economy.

3 Canadian Stylized Facts

Having laid the foundation for analyzing the implications of a relative price movement for aggregate and sectoral productivity, we examine Canadian stylized facts following the most recent commodity price appreciation, to help explain the adjustment process that the Canadian economy has undergone. We will empirically analyze our findings in section 4.

3.1 Relative price movements and sector adjustments[7]

Responding to buoyant growth in world economic activity, commodity prices started to ascend late in 2001 and rose nearly 118 per cent in real terms between 2002Q4 and 2008Q2, driven by a 200 per cent jump in real energy prices and a 57 per cent increase in non-energy commodity prices (Chart 1). Given Canada's position as a net exporter of base commodities, increased world demand for its products is translated into favourable terms-of-trade adjustments and real appreciation of the Canadian dollar.[8] While the terms of trade improved by 22 per cent, the Canadian dollar appreciated by over 58 per cent, up from its historical low of 62.7 cents U.S. reached in 2002Q1 (Chart 2). These changes in relative prices triggered structural adjustments within the Canadian economy.[9]

First, the relative price changes in favour of commodity prices led to a rapid expansion in the mining, oil, and gas extraction sector. Over the 2003–07 period, real GDP in the sector rose an average 1.7 per cent per year, a somewhat faster pace than the 1.4 per cent observed over the 1998–2002 period. Responding with some delay, real investment growth accelerated to an average of 9.8 per cent over 2003–07 (Chart 3). Employment in the sector increased by some 30 per cent and growth in hours worked shot up by 7.7 per cent per annum, on average, over the period 2003–07 (Charts 4 and 5). Labour shortages quickly became apparent, particularly in Alberta, where wages increased sharply beginning in 2005, averaging 4.5 per cent growth annually between 2003 and 2007 compared to the national average of 2.9 per cent (Chart 6).[10]

7. For the sake of comparability and uniformity, this section makes use, whenever possible, of the KLEMS database, Statistics Canada table 383-0021. Unless otherwise specified, all figures reported in this section are at annual rates.
8. It is clear that the rise in commodity prices is not the sole reason behind the appreciation of the Canadian dollar; other factors, such as the depreciation of the U.S. dollar, are at play.
9. Structural adjustments are clearly multifaceted and, given the geographical concentration of the different Canadian industries, the adjustments that the economy is currently undergoing also feature important regional aspects that will be discussed throughout this paper.
10. Based on labour force survey estimates, wages of employees by job permanence, union coverage, sex, and age group, average hourly wage rate, Statistics Canada.

Taking advantage of the buoyant Alberta labour market and helping to alleviate pressures on production capacities, net interprovincial migration to Alberta accrued to 120,000 people between 2004 and 2006, before slowing markedly to 10,000 people in 2007. It is worth noting that net migration from central Canada, the country's manufacturing heartland, is nowhere near the peak reached in the early 1980s following the oil shocks of 1973 and 1979.[11]

Wage spillovers from the resource sector to other sectors of the economy appear to have been contained (Chart 6). Labour compensation per hour grew, on average, by 5.3 per cent in the mining, oil, and gas extraction sector in 2003–07, compared to 4.1 per cent and 3.4 per cent in the non-tradable and manufacturing sectors, respectively (Chart 7).[12] The data thus suggest that wage pressures have been rather confined regionally and sectorally, with Alberta and the mining, oil, and gas extraction sector most affected.

New income and wealth originating from the rise in commodity prices fed demand for non-tradable goods and services. As a result, output growth picked up in the non-tradable sector starting in 2003 after having slowed down for four years. Gains were particularly important in the following sectors: construction; finance, insurance, and real estate; and wholesale and retail trade. Real investment spending in the non-tradable sector as a whole increased, on average, by 8.2 per cent per year over the 2003–07 period, an acceleration after a 2-year slump (Chart 3). In addition, as a result of its dynamism, the non-tradable sector of the economy created as many as 1.0 million new jobs between January 2003 and July 2008.

Over the recent period, the manufacturing sector has faced a rapid appreciation of the Canadian dollar, in addition to increased competition from Asian countries, especially China. After reaching a peak in 2000, prior to the 2000–01 U.S. economic slowdown, manufacturing output managed to grow, on average, by 0.2 per cent a year over the 2003–07 period, a much slower pace than the 3.9 per cent annual average posted over 1998–2002. Benefiting from declining import prices for investment goods, real investment growth in the sector picked up substantially, averaging 6.9 per cent over the 2003–07 period, compared to a decline of 5.4 per cent over 1998–2002 (Chart 3). From its peak in 2000, employment in the sector declined some 16.8 per cent by mid-2008, shedding close to 346,000 jobs, while hours worked declined, on average, by 1.2 per cent per annum over 2003–07. Meanwhile, compensation per hour in the manufacturing sector continued to grow, close to the decade-long average of 3.4 per cent (Chart 7).

On a regional basis, the manufacturing sector has fared somewhat better outside central Canada, particularly in Alberta, Manitoba, and New Brunswick, where employment has recently risen

11. While the current spike in energy prices is believed to be driven mostly by buoyant global demand, the 1970s energy price shocks were the result of supply constraints that led to a generalized economic slowdown. High unemployment throughout the Canadian economy therefore created the incentive for workers in central and eastern Canada to move to western provinces to acquire a job in the vibrant energy sector. This is not the case in central Canada today, where final domestic demand remains strong.
12. Based on indexes of labour productivity and related variables, by selected industries (NAICS), seasonally adjusted, Statistics Canada table 383-0012.

back to 2004 levels. A lesser degree of trade exposure, the proximity to primary sector wealth, and a distinct industry mix with production links to the extraction industries may have cushioned the impact of the currency appreciation.[13] Even in Quebec and Ontario, which account for 74 per cent of the Canadian manufacturing production, the relative price shock could have had a more negative effect were it not for the fact that these two provinces are important manufacturers of metal products and that the global economic recovery over the 2003–07 period supported demand for manufactured goods.

All sectors of the Canadian economy are currently experiencing the predicted adjustments, with related effects at the regional level. Deindustrialization appears to be limited, as evidenced by persistent labour shortages in the oil sector, and in the oil boom region more generally. Interprovincial barriers to labour mobility, such as distance, culture, language, and availability of affordable housing, play a role in containing deindustrialization. It appears unlikely that the bulk of new jobs in the mining, oil, and gas extraction sector have been filled by workers moving out of the Ontario or Quebec manufacturing sector. Given trends in wages, which have been increasing in the primary sector throughout Canada, workers from eastern Canada – particularly Newfoundlanders, who have working experience in the primary sector – appear to have made a disproportionate contribution to filling vacant positions in the oil boom region. In fact, Alberta's firms are courting Atlantic Canadian workers through a recrudescence of job fairs, while Albertan authorities are trying to partner local firms with firms in central Canada in an effort to alleviate constraints on production capacities. The manufacturing sector shed 221,000 jobs between January 2003 and July 2008, while the mining, oil, and gas extraction sector gained 60,000 new jobs and the non-traded sector of the economy created as many as 1.0 million new jobs. Furthermore, the labour force grew an average of 1.8 per cent per year and the participation rate increased from 66 per cent to 67.7 per cent.[14]

3.2 Recent and expected movements in labour productivity growth[15]

Adjustments in output and employment have direct implications for productivity figures. The data suggest that labour productivity growth in the mining, oil, and gas extraction sector averaged -1.7 per cent per annum over the 1998–2007 period.[16] Prior to the significant increase

13. For instance, Alberta's international imports-to-GDP ratio is 8 per cent, compared to 39 per cent for central Canada, suggesting that international competition is of lesser importance in that province. Likewise, the proportion of manufacturing shipments attributed to petroleum and coal product manufacturing is much greater in Alberta (23 per cent) than in Quebec (10 per cent) or Ontario (7 per cent). Source: Statistics Canada, table 304-0015, Manufacturing sales, by North American Industry Classification System (NAICS) and province, monthly (dollars).
14. Figures as of December 2007.
15. Labour productivity is defined as output per hour worked.
16. Productivity data for the mining, oil, and gas extraction sector and for the manufacturing sector are directly available from Statistics Canada's KLEMS database, table 383-0021. Consistent productivity for the non-tradable sector has been obtained by summing GDP at basic prices (1997 constant dollar) divided by the corresponding sum of hours worked for the following subset of industries: Construction (NAICS 23); Wholesale and Retail Trade (NAICS 41, 44-45); Transportation and Warehousing (NAICS 48-49); Information and Culture (NAICS 51); Finance, Insurance and Real Estate (NAICS 52-53); Professional, Scientific and Technical Services (NAICS 54); and Other Services (NAICS 81). Source: Statistics Canada tables 379-0018 and 383-0021.

in commodity prices, however, productivity growth averaged 2.2 per cent per year in that sector (1998–2002). Although productivity experienced rapid growth during the 2002 expansion, output quickly reached its peak capacity and the average annual productivity growth for the 2003–07 period slumped to an average of -5.5 per cent per year, at a time when the sector was absorbing rapidly increasing inputs of both labour and capital (Chart 8). This caused labour productivity in the mining, oil, and gas extraction sector to fall back to its 1990 level after having reached a peak in 1999. The level of productivity, however, is still relatively high, due to the high capital intensity of this sector, which is among the highest in the economy.

Meanwhile, a relatively rapid decline in the labour input, concomitant with the levelling off of production, has allowed the manufacturing sector to maintain a positive pace of labour productivity growth. However, labour productivity growth slowed down significantly from an average of 2.9 per cent during 1998–2002 to 1.7 per cent, on average, over the 2003–07 adjustment period (Chart 8), where the rapid appreciation of the Canadian dollar and increased competition from Asian countries forced the manufacturing sector to shed labour in search of efficiency gains. While the sector experienced a cyclical downturn in 2000–01 as the U.S. economy went through a short economic slump, it nevertheless posted an average productivity growth rate of 2.3 per cent per year over the 1998–2007 period.

Productivity in the non-tradable sector averaged 1.7 per cent per annum over the past decade. From 1998 to 2002, labour productivity grew, on average, 2.0 per cent per year. It then slowed significantly over the 2002–04 period, to rebound thereafter, averaging a growth rate of 1.4 per cent per year over 2003–07 (Chart 8). The slowdown in productivity growth was particularly marked in the following sectors: construction; retail trade; information and culture; finance, insurance, and real estate; and professional, scientific, and technical services.

Consequently, labour productivity growth in the business sector slowed from an average of 2.3 per cent between 1998 and 2002 to 1.1 per cent over the 2003–07 period (Chart 8), lending credibility to the cost-of-adjustment effects described earlier. Nevertheless, despite clear investment expansion across all sectors, in line with newly exposed incentives, it may be too early in the adjustment process for noticeable effects to become apparent in long-term labour productivity growth.

4 Empirical Analysis

We showed in section 2 that it is very difficult to determine analytically the implications for aggregate and sectoral labour productivity from a commodity price movement and ensuing sectoral adjustments. Yet, recent stylized facts, described in section 3, suggest that aggregate labour productivity growth declined, since it decreased in all three sectors. This fact lends support to the cost-of-adjustment theory, which predicted that intersectoral labour transfers would lead to some disruption of regular work in both declining and expanding sectors, with

negative consequences for productivity, at least in the short to medium run. We will now verify whether this result holds under empirical investigation, examining how relative price movements influence output and hours worked, and therefore aggregate and sectoral productivity growth, over a 20-year span, once we control for business cycle effects.

Using time-series analysis, we evaluate these implications using the vector autoregressive (VAR) approach. This approach allows us, with a minimum of restrictions, to investigate the relationship between relative prices and productivity (or its components, namely output and hours worked).

4.1 Methodology

Recall that the usual structural VAR (SVAR) assumes the following general form:

$$Ay_t = \Gamma_0 + \sum_{i=1}^{p} \Gamma_i y_{t-i} + \varepsilon_t ,$$

where y_t is a (n x 1) vector of endogenous variables, A is an invertible *(*n x n*)* matrix of contemporaneous coefficients, Γ_0 is the (n x 1) intercept vector, Γ_i is the ith (n x n) matrix of autoregressive coefficients for i = 1, 2, …, p, and e_t is the (n x 1) vector of structural innovations.

The structural innovations (ε_t) can be recovered from the observed residuals (e_t) through the following relationship $\varepsilon_t = Ae_t$. However, given this estimation scheme, the structural model is underidentified and needs to be restricted in order to be recovered from the reduced form. A number of methods can be applied to the system in order to achieve this goal. However, following Sims (1986) and Bernanke (1986), economic theory is applied to identify the underlying structural shocks from the reduced-form model. In other words, in this SVAR approach, the A matrix will be constrained on the basis of economic priors.

We explore two related specifications in order to determine the role of relative price movements on productivity and its components – output and hours worked. First, eliminating the sector issue brought forth by the literature cited above, we investigate the effect of relative price movements on aggregate output and hours worked using a simple 4-variable VAR that includes the U.S. real GDP as a proxy for the business cycle (y^{us}), the Bank of Canada's real commodity price index as a measure of relative prices (*bcpi*),[17] and aggregate output and hours worked, the components

17. Relative prices can be measured in many different ways. For example, the terms of trade and the exchange rate are two other potential measures for the more broadly defined "relative prices." We opt to include real commodity prices in our model, since they are at the heart of recent movements in both Canadian terms of trade and the exchange rate. However, for the sake of completion, we have estimated our model using the terms of trade and the exchange rate in place of the real BCPI, with no material differences in the results.

of aggregate labour productivity (h_{agg} and y_{agg}).[18,19] Since we want to capture the long-run effect of a change in relative prices on labour productivity, it will be important to control for the short-run business cycle effect. By doing so, we should capture supply and demand forces that generate persistent changes in relative prices. These price movements should, in turn, trigger reallocation of output and hours worked (and employment), and therefore changes in labour productivity.

In this particular VAR framework, we implicitly assume that output is a function of land, technology, capital, labour, and intermediate inputs, while the underlying choice of factor inputs (including labour) is assumed to be a function of relative factor prices. We do not explicitly model the production function and are interested only in identifying a relative price shock that, through its influence on relative factor prices, will ultimately affect output, employment, hours worked, and productivity.

Once the overall impact is estimated for aggregate productivity, a series of similar models are built with sectoral output and hours worked to investigate sectoral labour productivity. The implicit objective is to identify idiosyncratic responses of sectoral output, hours worked, and hence productivity to a movement in relative prices.[20] We define our sector along the Corden and Neary (1982) framework. Hence, relevant to the Canadian case, growth of output and hours worked will be partitioned between the booming primary sector (*pri*), a lagging manufacturing sector (*mfg*), and the non-tradable sector (*nt*), which leads us to construct three more (one for each sector) 4-variable SVARs.

In order to identify the underlying structural innovations from the model's residuals, we opt for the following ordering of the SVAR. Since we are interested in the implication of a relative price shock for labour productivity (through adjustments to output and hours worked) while controlling for the business cycle, it is clear that our proxy for the business cycle (U.S. GDP) will appear first in the model, followed, respectively, by our relative price measure (real BCPI). The ordering of output and hours worked is not necessarily intuitive. However, both variables tend to evolve in tandem through the economic cycle and, in fact, their respective growth rates are strongly contemporaneously correlated at the quarterly frequency, which suggests that their ordering should not be of any consequence for the results.[21] Hence, in the case of our 4-variable systems, it appears that we can justify the Choleski decomposition on the basis of theory and

18. For the purpose of our estimation, the data on hours worked are taken from the LFS database, as opposed to the KLEMS database for the stylized facts (section 3). We needed to revert back to LFS data for two reasons: (i) the availability of quarterly data, and (ii) the need to aggregate subsectors of the non-tradable sector, which KLEMS indexed data do not allow for.
19. The analysis was also conducted using employment to measure the labour productivity ratio. The results were similar.
20. As a first step, we look at the sectoral aspect (as opposed to the regional aspect) of the adjustment in order to be consistent with Corden and Neary's 3-sector model. Data on productivity are often considered more reliable and informative at the sectoral level, while regional data would probably not be very helpful in better understanding aggregate productivity, since the differences in trend productivity growth are rather sectoral. The only comparative advantage of a regional analysis is the availability of interprovincial migration data. No such data exist on intersectoral labour movements.
21. In fact, further investigation reveals that interchanging the ordering does not materially affect the model's results.

thus identify a structural terms-of-trade shock to the system. The following restrictions therefore will be applied to the contemporaneous innovations:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} e_t^{yus} \\ e_t^{bcpi} \\ e_t^{h} \\ e_t^{y} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{yus} \\ \varepsilon_t^{bcpi} \\ \varepsilon_t^{h} \\ \varepsilon_t^{y} \end{bmatrix}.$$

Furthermore, given the "small and open" nature of the Canadian economy in the global setting, we need to acknowledge the exogenous character of U.S. GDP. We do so by restricting the coefficient on the lags of real BCPI, growth of output, and growth of hours worked in the U.S. GDP growth equation to be zero. One could argue, however, that the U.S. GDP could be affected by an important movement in commodity prices. Although this is true, we also estimated our models with U.S. GDP responding endogenously to a shock to the BCPI, and this did not materially affect the results for output and hours worked.

In an alternative specification of the model, we also controlled for the monetary policy response to an important commodity price appreciation on output and hours worked by including the slope of the yield curve in our model specification. The monetary authority is likely to react to a commodity price shock either to smooth the adjustment of output and employment or to contain the pass-through of commodity price inflation to consumer prices. However, since the addition of the slope of the yield curve did not materially influence the results, we decided to keep it out of our main model specification in the interest of preserving degrees of freedom.

Before estimating the models, a series of unit root tests were applied to the series in the study in order to determine their order of integration. Specifically, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were performed, and they suggest that all variables are integrated of order 1. Hence, all variables are introduced in the models in first-difference logarithmic form for the purposes of stationarity. The model is estimated on a quarterly basis and the sample covers from 1987Q2 to 2007Q4.[22]

4.2 Results

4.2.1 Aggregate model results

The lag length of the models was determined using the Akaike and Schwarz Information Criterion, as well as likelihood ratio tests. Lags were then added to the pre-selected lag length

22. The starting date for the sample is constrained by the availability of data on sectoral hours, which are not available at the quarterly frequency for the 2-digit NAICS code prior to 1987.

(usually, one or two lags), to ensure that the models' residuals were white noise. For consistency in estimation, we opted for three lags to be the optimal order. The analysis of the impulse-response function (IRF)[23] for the relationship of interest in the study suggests that a one standard deviation shock to real commodity price growth has small positive consequences for growth of aggregate output and hours worked on impact, followed by a slowing of growth after two quarters, and then subsiding completely after five quarters. Since hours worked tend to be somewhat more responsive than output, aggregate labour productivity growth is affected negatively upon impact and through the first quarter. However, the impact of this shock is at no point statistically different from zero at the 4-year horizon (Chart 9) when using 90 per cent confidence intervals obtained through bootstrapping methods.

4.2.2 Sectoral productivity model

In response to a one standard deviation shock to real commodity prices, hours worked in the primary sector appear to increase, peaking three quarters after the price shock, and dissipating almost entirely after eight quarters (Chart 10). Simultaneously, output growth does not appear to rise notably, resulting in downward pressure on labour productivity growth in the sector. There are three possible reasons why extra hours worked generate proportionately less output in the primary sector. First, newly hired workers would be expected to be less productive on the margin than experienced ones; second, efforts early in the production cycle for base commodities are often devoted to less-productive activities, such as exploration and deposit-appraisal expenditures, and lead time is particularly long in this sector; third, high prices permit the profitable exploitation of poorer deposits even as they require more capital and labour to achieve a given output level. Hence, labour productivity growth in the sector is affected negatively within four to eight quarters.

Furthermore, according to our model specifications, a real commodity price shock lowers hours worked and output growth in the manufacturing sector (Chart 11), in line with the literature and its weak presumption in favour of deindustrialization. However, since growth of hours worked appears to decline more than growth of output, the initial shock would suggest an increase in manufacturing labour productivity growth in the first few quarters following the shock to real commodity prices. The maximum impact on labour productivity is attained three quarters after the shock, and it then slowly reverts back to zero after about two years. As expected, this result suggests that a decline in labour input, concomitant with the levelling off of production, would be expected to allow the manufacturing sector to maintain a positive pace of labour productivity growth following an important real commodity price shock.

On impact, and for the first four quarters (except for the second quarter), the real commodity price shock tends to increase growth in hours worked in the non-tradable sector. Concurrently, the impact on growth of output appears to be slightly negative (Chart 12). Therefore, except for a

23. The complete set of impulse-response functions is available from the authors upon request.

positive blip in the second quarter following the initial shock to real commodity prices, labour productivity growth in the non-tradable sector is negatively affected during the first year of the adjustment period. Given the relatively large size of the non-tradable sector, this result is likely to be a major driver for the slightly negative, but statistically insignificant, impact of a commodity price shock on aggregate labour productivity.

Overall, the results obtained from the VAR model are broadly consistent with the analysis of the stylized facts, but no impulse response is statistically significant. It is therefore impossible to say with confidence how productivity growth would move following the type of relative price change studied here based on our VAR analysis. Cao and Leung (2010) examine the determinants of labour flows both between industries and between firms within industries, and their relationship with productivity growth. While their regression analysis suggests that changes in relative prices can account for a large fraction of employment reallocation, these shifts between industries seem to have little positive impact on aggregate labour productivity growth. Cao and Leung find that it is the gross flows of labour within industries, rather than net labour flows between industries, that are positively related to labour productivity growth rates. This might suggest that a more disaggregated analysis of the labour reallocation after a relative price change would be more appropriate to better understand the implications for labour productivity.

5 Concluding Remarks

A significant movement in relative prices as measured by the Bank of Canada real commodity price index, while leading to significant resource reallocations, could also affect sector and/or aggregate productivity growth during the adjustment process. There are three types of potential effects. First, the resource reallocation towards the primary sector should help improve productivity, while redirected resources from the manufacturing sector towards the non-tradable sector should lower productivity through the accounting effect.[24] Statistical evidence indicates that the net of the accounting effect is negative, since the shares of the extraction and the manufacturing sectors to GDP have fallen recently in favour of the non-tradable sector. Second, the cost-of-adjustment effect implies a reduction in labour productivity, since it is generally agreed that intersectoral labour transfers lead to some disruption of regular work, in both declining and expanding sectors. Finally, economic incentives are likely to be modified following the relative change in factor costs triggered by the currency appreciation that accompanies the commodity price increase, with a presumption that lower costs for imported investment goods in Canada could have positive consequences for long-term productivity growth. However, the overall impact on aggregate and sectoral labour productivity growth from an important commodity price appreciation remains difficult to identify analytically.

24. Given the sectors' current relative capital-labour ratios, productivity levels are higher in the primary, manufacturing, and non-tradable sectors, respectively.

Our empirical results suggest that an increase in commodity prices, with a subsequent improvement in Canadian terms of trade and Canadian dollar appreciation, has a detrimental impact on labour productivity growth in the primary sector, a positive impact on manufacturing labour productivity growth, and a marginally negative impact on labour productivity growth in the non-tradable sector. Given the size of the non-tradable sector in the economy, the overall effect of a positive commodity price shock to aggregate labour productivity growth would appear to be marginally negative within the first year, with the exception of the second quarter, before diminishing thereafter. At no time is the aggregate labour productivity IRF significantly different from zero. In the longer run, the improvement in the terms of trade should lower the relative price of capital and encourage the substitution of capital for labour, which could contribute to higher labour productivity growth.

A caveat remains: it is always difficult to assert with conviction a causal relationship within a reduced-form framework. A structural framework would be the natural extension to this research.

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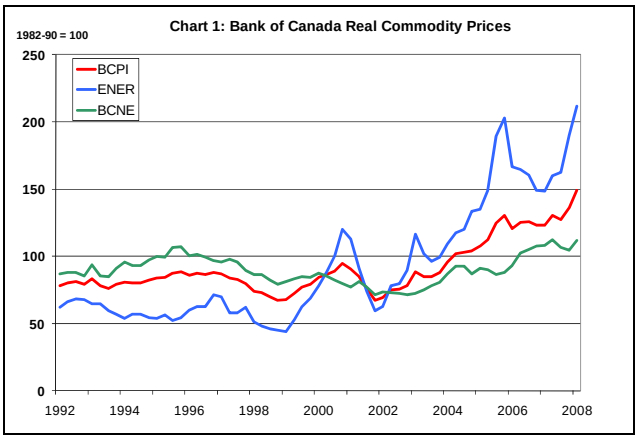


Chart 1: Bank of Canada Real Commodity Prices
1982-90 = 100
250
200
150
100
50
0
BCPI
ENER
BCNE
1992
1994
1996
1998
2000
2002
2004
2006
2008

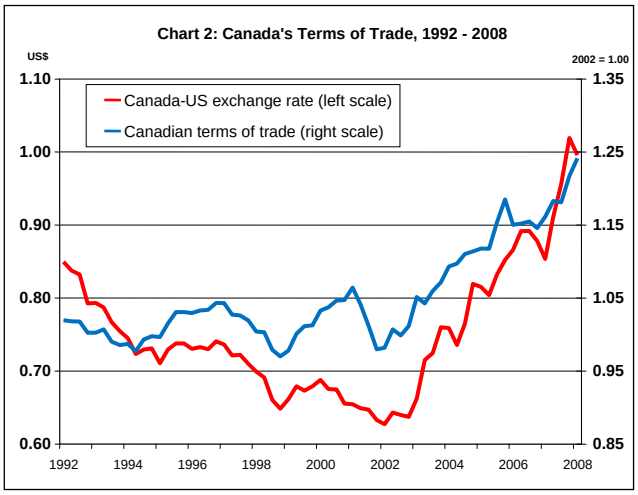


Chart 2: Canada's Terms of Trade, 1992 - 2008
US$
2002 = 1.00
1.10
1.00
0.90
0.80
0.70
0.60
1.35
1.25
1.15
1.05
0.95
0.85
Canada-US exchange rate (left scale)
Canadian terms of trade (right scale)
1992
1994
1996
1998
2000
2002
2004
2006
2008

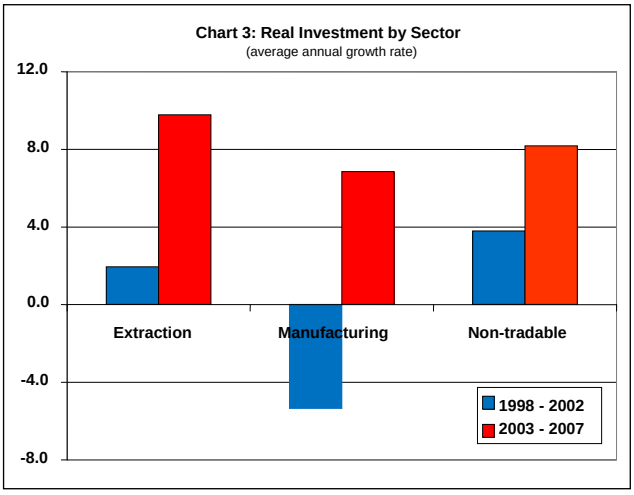


Chart 3: Real Investment by Sector
(average annual growth rate)
12.0
8.0
4.0
0.0
-4.0
-8.0
Extraction
Manufacturing
Non-tradable
1998 - 2002
2003 - 2007

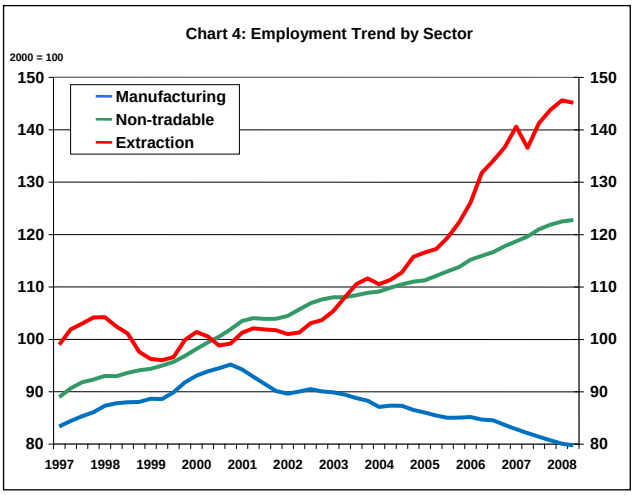


Chart 4: Employment Trend by Sector
2000 = 100
Manufacturing
Non-tradable
Extraction
150
140
130
120
110
100
90
80
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

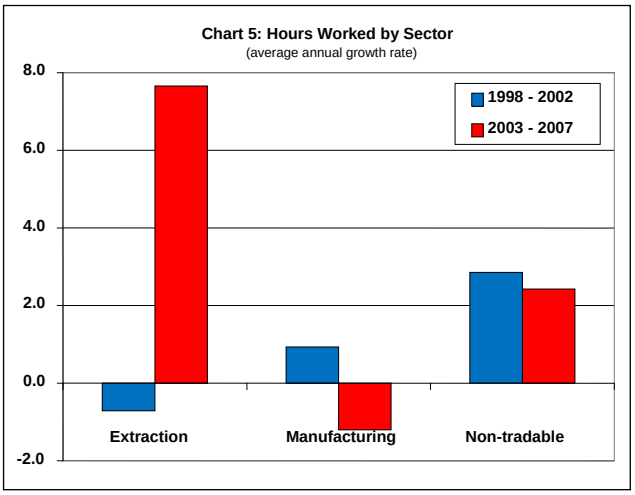


Chart 5: Hours Worked by Sector
(average annual growth rate)
1998 - 2002
2003 - 2007
8.0
6.0
4.0
2.0
0.0
-2.0
Extraction
Manufacturing
Non-tradable

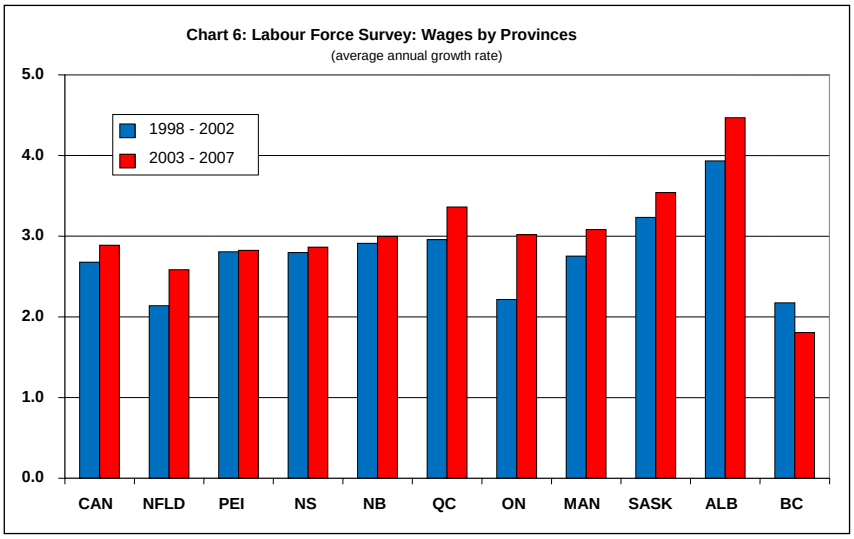


Chart 6: Labour Force Survey: Wages by Provinces
(average annual growth rate)
1998 - 2002
2003 - 2007
5.0
4.0
3.0
2.0
1.0
0.0
CAN
NFLD
PEI
NS
NB
QC
ON
MAN
SASK
ALB
BC

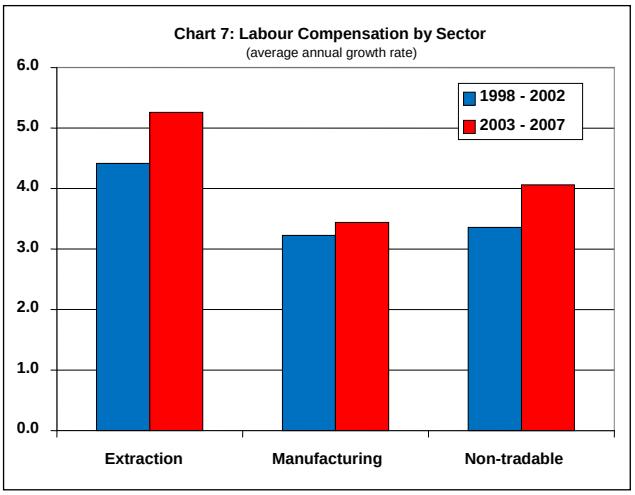


Chart 7: Labour Compensation by Sector
(average annual growth rate)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1998 - 2002
2003 - 2007
Extraction
Manufacturing
Non-tradable

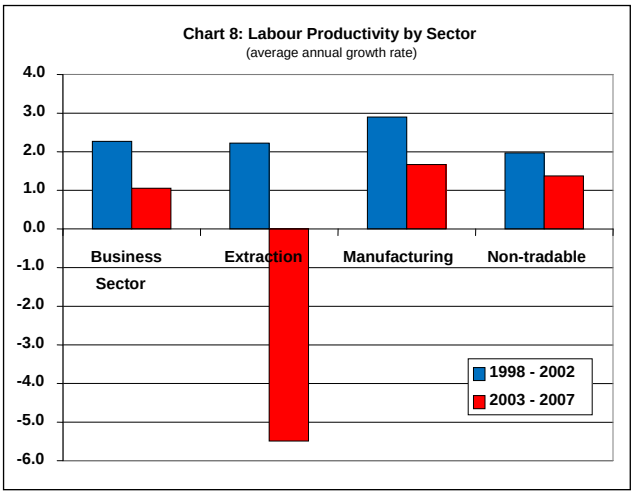
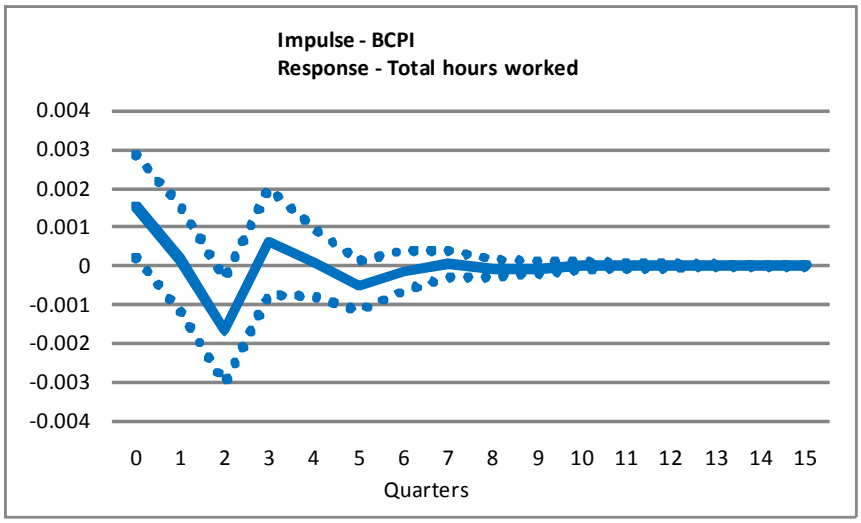
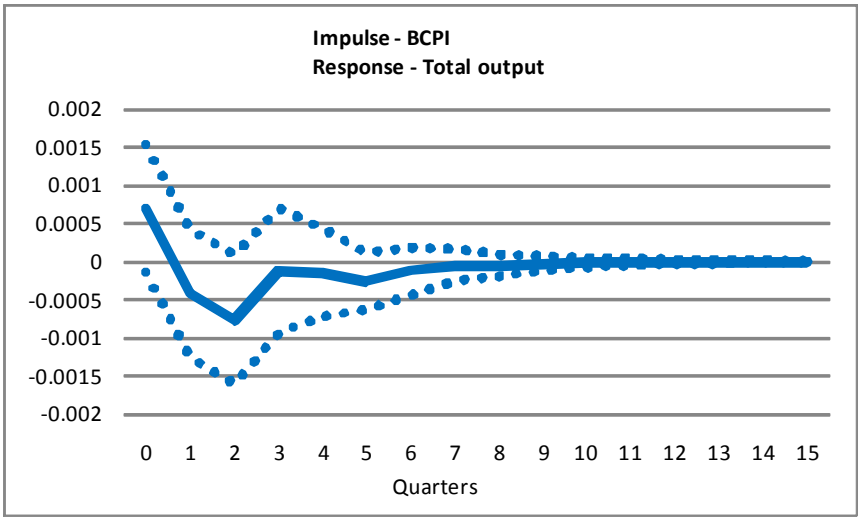


Chart 8: Labour Productivity by Sector
(average annual growth rate)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
Business Sector
Extraction
Manufacturing
Non-tradable
1998 - 2002
2003 - 2007

Chart 9: Structural IRF of a Real Commodity Price Shock
to Aggregate Output, Hours Worked, and Labour Productivity





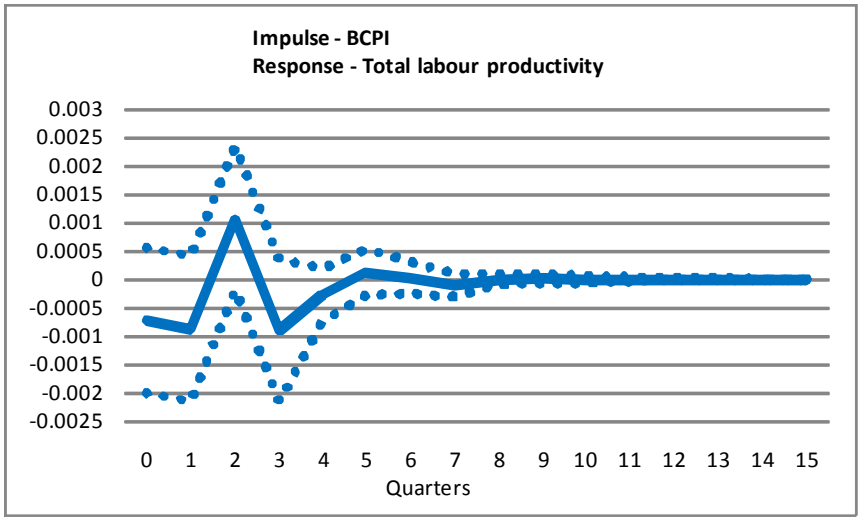
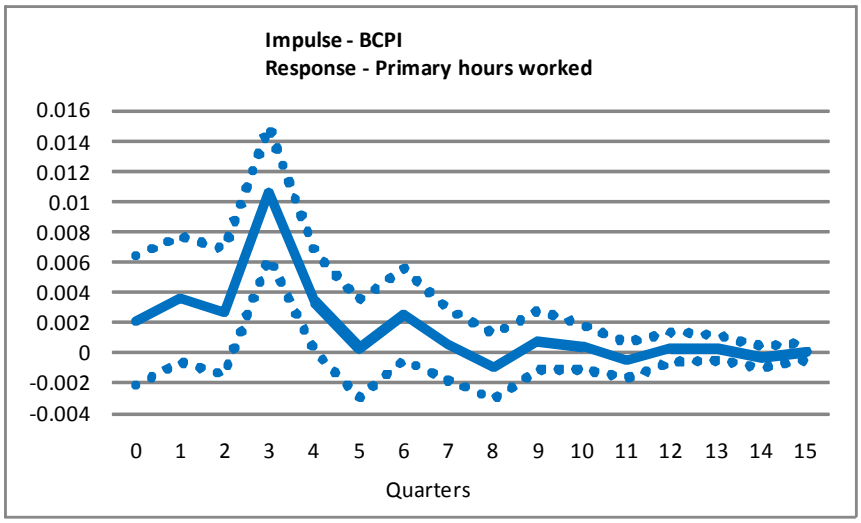
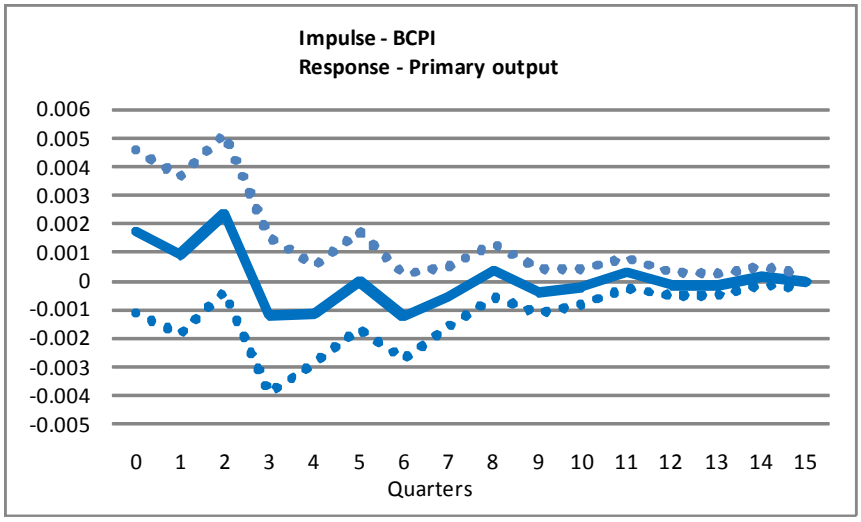


Chart 10: Structural IRF of a Real Commodity Price Shock
to Primary Sector Hours Worked, Output, and Labour Productivity





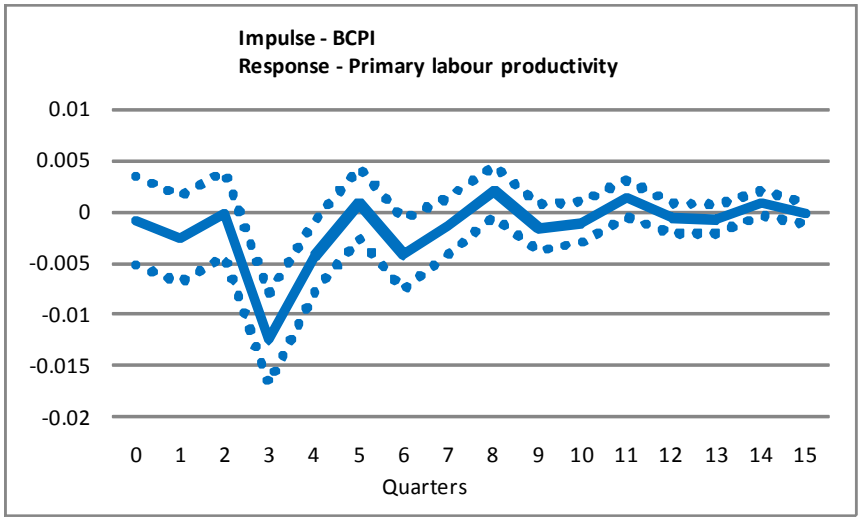
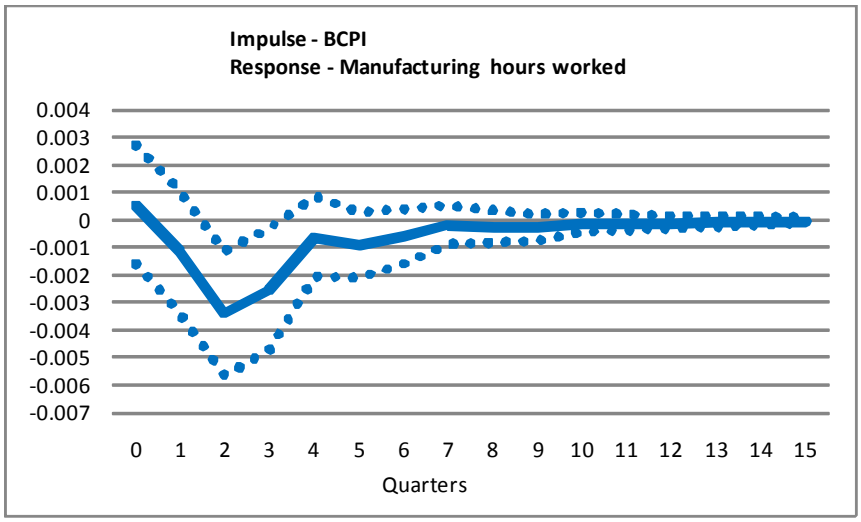
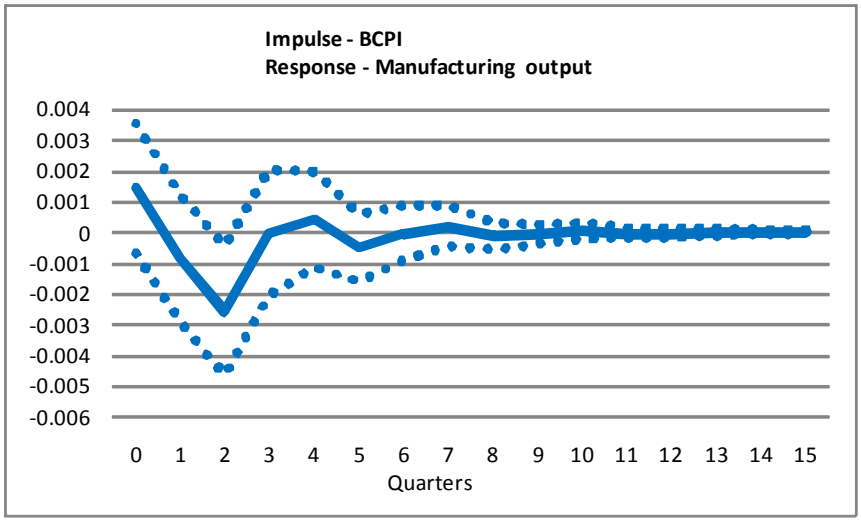


Chart 11: Structural IRF of a Real Commodity Price Shock
to Manufacturing Sector Hours Worked, Output, and Labour Productivity





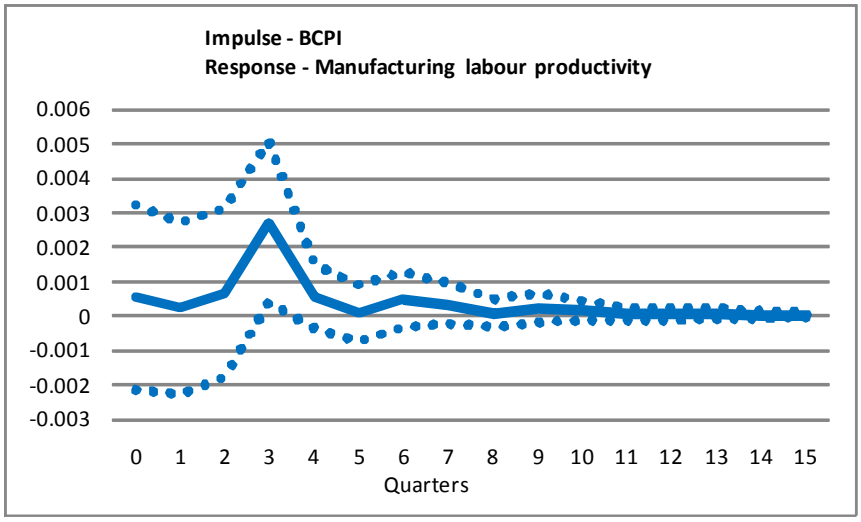


Chart 12: Structural IRF of a Real Commodity Price Shock
to Non-Tradable Sector Hours Worked, Output, and Labour Productivity