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Gabriel Bruneau[1] and Kevin Moran[2]

[1]Financial Stability Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
gbruneau@bankofcanada.ca

[2]Department of Economics
Université Laval, Quebec
kmoran@ecn.ulaval.ca

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Abstract

We estimate the link between exchange rate fluctuations and the labour input of Canadian manufacturing industries. The analysis is based on a dynamic model of labour demand, and the econometric strategy employs a panel two-step approach for cointegrating regressions. Our data are drawn from a panel of 20 manufacturing industries from the KLEMS database and cover a long sample period that includes two full cycles of appreciation and depreciation of the Canadian dollar. Our results indicate that exchange rate fluctuations have significant long-term effects on the labour input of Canada's manufacturing industries, that these effects are stronger for trade-oriented industries, and that these long-term impacts materialize only gradually following shocks.

JEL classification: E24, F14, F16, F31, F41, J23
Bank classification: Exchange rates; Exchange rate regimes; Econometric and statistical methods; Labour markets; Recent economic and financial developments

Résumé

Nous examinons le lien entre les variations du taux de change et celles du facteur travail dans les industries manufacturières canadiennes. Notre analyse est fondée sur un modèle dynamique de la demande de travail, et notre méthode économétrique met à profit une approche en deux étapes pour données de panel, afin d'estimer les relations de cointégration. Nos données sont tirées d'un panel de 20 industries manufacturières provenant de la base de données KLEMS et couvrent une longue période comprenant deux cycles complets d'appréciation et de dépréciation du dollar canadien. Nos résultats montrent que les fluctuations du taux de change ont d'importantes répercussions à long terme sur le facteur travail des industries considérées, que ces effets sont plus marqués dans les secteurs à vocation exportatrice et que ces incidences à long terme ne se matérialisent que progressivement à la suite de chocs.

Classification JEL : E24, F14, F16, F31, F41, J23
Classification de la Banque : Taux de change; Régimes de taux de change; Méthodes économétriques et statistiques; Marchés du travail; Évolution économique et financière récente

Non-Technical Summary

The labour market response to fluctuations in the exchange rate has drawn strong interest over the past decade, as concerns emerged that the higher value of the Canadian dollar would cause protracted declines in manufacturing jobs. Conversely, the more recent period of depreciation of the currency has led to conjecture about whether manufacturing in Canada will rebound.

This paper provides a quantitative analysis of the link between exchange rate fluctuations and the labour input of manufacturing industries. Specifically, we ask the following questions: (i) What are the long-term impacts of changes to real exchange rates on manufacturing hours and jobs? (ii) How fast do the adjustments towards these long-term impacts take place? To address these questions, the paper formulates a model of labour demand and estimates it using data spanning from 1961 to 2008, thus covering all the major shifts in the real value of Canada's currency over the past 50 years.

We report four main findings. First, exchange rate fluctuations have sizeable effects on hours worked and jobs in Canadian manufacturing industries. Second, these adjustments occur relatively slowly. Third, these effects are stronger for industries with a high exposure to international trade. Finally, we document that the enactment of two major trade deals between Canada and its North American partners has had significant negative impacts on the labour input of Canadian manufacturing firms.

1 Introduction

The influence of exchange rates on Canadian manufacturing industries has attracted much attention historically. The past decade's sustained appreciation of the Canadian dollar relative to its U.S. counterpart has proven to be no exception, as concerns were raised that the high value of the Canadian dollar was contributing to protracted declines in manufacturing jobs. Conversely, the more recent period of depreciation of the currency has led to conjecture about whether manufacturing in Canada will rebound.

Figure 1 illustrates the evolution of the real value of the Canadian dollar and that of total hours worked in manufacturing between 1961 and 2008.[1] The figure shows that the pronounced cycles of depreciation and appreciation experienced by the Canadian dollar over the past 50 years appear to have been negatively correlated with hours worked in manufacturing. For example, the 1990s were characterized by a steady depreciation of the Canadian dollar and, throughout this period, hours worked in manufacturing were increasing. Conversely, the early 2000s witnessed a rapid appreciation of the currency at the same time as important retrenchments in manufacturing hours occurred.

This paper provides a quantitative analysis of the link between exchange rate fluctuations and the labour input of manufacturing industries. We ask the following questions: (i) What are the long-term impacts of changes to real exchange rates on manufacturing hours and jobs? (ii) How fast do the adjustments towards these long-term impacts take place? To address these questions, the paper formulates a dynamic labour-demand model and estimates it using a panel cointegrating approach with an error-correcting mechanism. The data used to estimate the model are from KLEMS,[2]

[1]The real effective exchange rate measure is from a database created by *Bruegel* that provides real effective exchange rates for several countries. Nominal rates are deflated by pairwise relative CPIs and are weighted by trading importance; an increase represents an appreciation of the Canadian dollar. Hours worked is for all manufacturing industries and is from the KLEMS database. Details on the data used in this paper are presented below.

[2]KLEMS (from Statistics Canada) stands for **K**apital, **L**abour, **E**nergy, **M**aterial and **S**ervices.

an industry-level database of panel data organized under the North American Industry Classification System (NAICS) that spans the period from 1961 to 2008, covering all major shifts in the real value of Canada's currency over the past 50 years.

We report four main findings. First, exchange rate fluctuations have sizeable effects on hours worked and jobs in Canadian manufacturing industries. Under our benchmark specification, a 10 percent real depreciation of the Canadian dollar is associated with a 3 percent increase in hours worked and an increase just under that for the number of jobs. Second, these adjustments occur relatively slowly, with about 13 percent of the gap between actual and targeted labour (defined below) closed each year. Third, these effects are stronger for industries with a high exposure to international trade. Finally, we document that the enactment of two major trade agreements between Canada and its North American trading partners has had significant negative impacts on the labour input of Canadian manufacturing firms.

An earlier related paper is Leung and Yuen (2007), who also study the impact of exchange rate fluctuations on the labour input of Canadian manufacturing firms. The current paper offers two important contributions relative to Leung and Yuen (2007). First, we use a substantially longer sample (1961-2008) that allows our analysis to cover all important shifts in the external value of the Canadian dollar over the past 50 years. Second, this longer dataset permits the use of an econometric methodology focusing on the long-term adjustments to exchange rate shifts. To this end, we first estimate a (panel) cointegrating relationship between the labour input of manufacturing firms, the real effective exchange rate, and other economic variables. Once the cointegrating vector is established, we then evaluate the speed at which gaps between actual and targeted values of variables are corrected.[3] Our analysis can thus bring to bear information contained in both the long-term relationship between exchange rates and labour, as well as in the dynamic adjustment towards that long-term relationship.

Other related work includes Campa and Goldberg (2001), who study the adjustment

[3] The shorter sample (1981-1997) available to Leung and Yuen (2007) prevented them from focusing on long-term adjustments, and they did not use cointegration techniques.

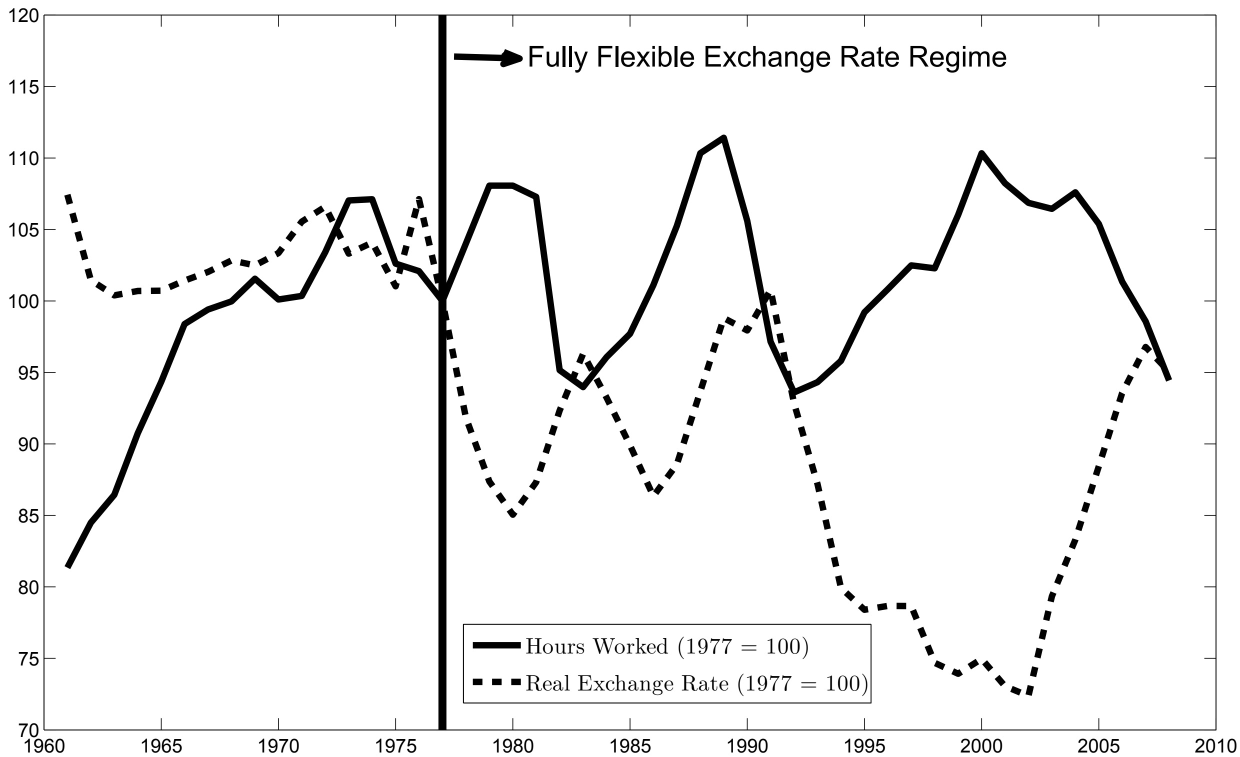

Figure 1: Real Effective Exchange Rate of the Canadian dollar versus Hours Worked in Manufacturing (All Industries, 1977=100, 1961-2008).

of American manufacturing firms to U.S.-dollar fluctuations and find no significant impact on employment and hours worked. By contrast, Dekle (1998) reports that changes in the external value of the yen have significant effects on Japanese manufacturing employment. Burgess and Knetter (1998), studying a set of industrialized countries, report that exchange rate fluctuations have very small impacts on manufacturing employment in some countries, such as Germany and France, but have significant impacts in others, including the U.S., Canada and the U.K. None of these studies apply econometric strategies designed to allow cointegrated variables and identify long-term adjustments.

The remainder of this paper is organized as follows. Section 2 presents our theoretical model and the empirical specification. Section 3 introduces the data employed in the estimation, which are taken from the most recent release of the KLEMS database.

Section 4 presents the methodology and Section 5 reports our estimation results and assesses their robustness through an extensive sensitivity analysis. Finally, Section 6 concludes. A detailed description of all data used is provided in the Appendices.

2 Model

This section develops an econometric model to analyze the long- and short-term impacts of exchange rate fluctuations on the labour input of Canadian manufacturing firms. The model assumes that Canada's manufacturing firms operate in monopolistically competitive environments in both their domestic and foreign markets. Accordingly, firms maximize profits by choosing their product's relative price, subject to a production function, to input prices for which they are price-takers and to labour adjustment costs.

In this context, assume that worldwide demand for the product of firm i is expressed as

$$y_{i,t}^{d} = x_{i,t} p_{i,t}^{-\theta}, \tag{1}$$

where $p_{i,t}$ is the firm's relative price, θ is the price elasticity of demand, and $x_{i,t}$ indexes the overall demand for goods. The product-demand shifter $x_{i,t}$ first depends on the real exchange rate s_t between Canada and its trading partners. An increase in s_t represents a real appreciation that reduces the ability of domestic firms to export profitably and allows foreign imports to enter more easily into Canada. We therefore expect s_t to have a negative impact on $x_{i,t}$. Next, $x_{i,t}$ depends on worldwide demand for Canadian goods y_t^{all}, which we measure by an aggregate of Canada's GDP and that of its trading partners.[4] We expect a positive impact from y_t^{all}. Finally, we allow $x_{i,t}$ to be affected by the enactment of two major trade agreements (the Canada-U.S. Free Trade Agreement in 1989 and the North American Free Trade Agreement in 1994), as well as the switch to floating exchange rates between the Canadian and U.S.

[4] The notation y_t^{all} reflects the influence of both domestic and foreign demand (the sum of Y_t and Y_t^* in the model derived in Appendix C). Our empirical work measures y_t^{all} as the $G7$ aggregate of real GDPs produced by the OECD, but our results are robust to alternative measures of world demand for Canada's manufacturing products.

dollars in the 1970s.

Next, assume that the production function for firm i is

$$y_{i,t} = a_{i,t} F\left(l_{i,t}, k_{i,t}, ii_{i,t}\right), \tag{2}$$

where $a_{i,t}$ is multifactor productivity in industry i at time t, $l_{i,t}$ is a (quality-weighted) labour input, $k_{i,t}$ is the capital input, $ii_{i,t}$ is the input of intermediate goods, and $F(\cdot)$ is a constant returns-to-scale production function.[5] The price of labour in industry i is denoted by $w_{i,t}$, while the prices for capital and intermediate inputs are $p^K_{i,t}$ and $p^{II}_{i,t}$, respectively.

Consider first a frictionless choice of the labour input, when no adjustment costs are present. Maximizing profits subject to (1) and (2) yields the following expression:

$$\begin{aligned} \ln l^*_{i,t} &= \alpha_{i,0} + \alpha_1 \ln w_{i,t} + \alpha_2 \ln p^K_{i,t} + \alpha_3 \ln p^{II}_{i,t} + \alpha_4 \ln a_{i,t} + \alpha_5 \ln s_t + \\ &\quad \alpha_6 \ln y^{all}_t + \alpha_{i,7} CUSFTA_t + \alpha_{i,8} NAFTA_t + \alpha_{i,9} FEX_t + \varepsilon^{LT}_{i,t}, \end{aligned} \tag{3}$$

where $CUSFTA_t$ and $NAFTA_t$ are time dummies controlling for the two trade agreements, while FEX_t indexes the transition towards floating exchange rates in the 1970s. Appendix C derives (3) in the case of a two-input CES production function. It shows that the own-price elasticity parameter α_1 must be negative, but that the signs of α_2 and α_3 can vary according to the strength of substitution between labour and other inputs. It also describes how $\alpha_4 > 0$, $\alpha_5 < 0$ and $\alpha_6 > 0$.[6] In expression (3), fluctuations in the real exchange rate can affect labour input through two channels: first, a direct (demand) effect that arises because exchange rate fluctuations affect the demand of trade-oriented firms (the parameter α_5); second, an indirect effect that arises if one of the production inputs is imported, so that real exchange rate

[5] The KLEMS database is also constructed using a constant returns-to-scale framework.

[6] Note that the coefficients on prices and aggregate variables are common across industries, while the time dummies are allowed to have industry-specific effects. Specifications in previous versions of the research included an industry-specific time trend to account for the possibility of a secular decline in manufacturing sector activities and the results were quantitatively similar.

fluctuations affect its relative price and thus also labour demand through a substitution channel. Such an effect is most likely to be sizeable for Canadian manufacturing firms in the case of the capital input.

Starting with Nickell (1987), a large body of literature has assumed that adjustment costs prevent the frictionless labour input $l^*_{i,t}$ in (3) from being obtained. Instead, this literature (Burgess and Knetter, 1998; Dekle, 1998; Campa and Goldberg, 2001; Leung and Yuen, 2007) derives a partial-adjustment process towards the long-run "target" labour input $l^*_{i,t}$, as in

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu) \ln l^*_{i,t},$$

or, written differently,

$$\Delta \ln l_{i,t} = -(1-\nu)\left(\ln l_{i,t-1} - \ln l^*_{i,t}\right), \tag{4}$$

where $(1-\nu)$ is the speed of adjustment towards the long-run targeted labour input.

Since our data are shown to be integrated and cointegrated, a natural interpretation of equations (3) and (4) is that of a cointegrating relationship with an error-correction mechanism. Accordingly, our econometric strategy, discussed in detail below, involves first estimating the long-run relationship (3) and then the following generalized version of (4):

$$\Delta \ln l_{i,t} = -(1-\nu)\left(\ln l_{i,t-1} - \ln l^*_{i,t}\right) + \sum_{s=1}^{p} \delta^y_{s,i} \Delta \ln l_{i,t-s} + \sum_{s=0}^{p} \delta^X_{s,i} \Delta \ln X_{i,t} + \varepsilon^{ST}_{i,t}, \tag{5}$$

where $X_{i,t} = \{w_{i,t}, p^K_{i,t}, p^{II}_{i,t}, a_{i,t}, s_t, y^{all}_t\}$. Our estimation strategy uses the methods described in Breitung (2005) and Pesaran, Shin, and Smith (1999), which allow the intercepts (and other coefficients on deterministic regressors), short-run coefficients and error variances to differ across industries, but constrain the long-run coefficients to be the same.[7]

3 Data

A balanced panel of annual data for the Canadian manufacturing sector is used to estimate equations (3) and (5). The database includes both industry-specific and aggregate data and spans from 1961 to 2008.

The industry-specific data are from the KLEMS database. KLEMS, from Statistics Canada's Canadian Productivity Accounts, provides annual data on prices and quantities of output, as well as on capital, labour and intermediate inputs for all Canadian industries. The database is organized under the NAICS, and the data we use pertain to the 20 manufacturing industries at the 3-digit industry level.[8] KLEMS provides us with data for the quality-weighted labour input $l_{i,t}$, the hours worked $h_{i,t}$, the number of jobs $j_{i,t}$, multifactor productivity $a_{i,t}$, and, when used in combination with the Industrial Product Price Indexes, the relative price of labour $w_{i,t}$, the relative user cost of capital $p^K_{i,t}$, the relative price of intermediate inputs $p^{II}_{i,t}$ (a weighted average of the relative prices of energy $p^E_{i,t}$,[9] materials $p^M_{i,t}$, and services $p^S_{i,t}$) for all industries $i = 1, \ldots, N$ with $N = 20$ and for all time periods $t = 1, \ldots, T$ with $T = 48$. A complete description of these variables is provided in Appendix A.

Our empirical analysis uses the three alternative measures of the labour input from KLEMS: $h_{i,t}$, $l_{i,t}$ and $j_{i,t}$. First, $h_{i,t}$ represents a simple sum of the hours worked for all workers in industry i. Next, $l_{i,t}$ provides a quality-weighted sum of hours that controls for the education and experience of the workers. Our benchmark results are based on this measure. Finally, the variable $j_{i,t}$ represents total jobs in the sector,

[7]The existing literature on dynamic labour input adjustments does not recognize the presence of a cointegrating relationship between variables. Consequently, contributions to this literature generally estimate adjustment processes similar to (5) but without cointegration vectors and error-correction mechanisms.

[8]The NAICS codes 313 and 314 are aggregated in the KLEMS database.

[9]The Canadian exchange rate is highly correlated with commodity prices (Issa, Lafrance, and Murray, 2008). The inclusion of $p^E_{i,t}$ allows us to capture and isolate this relationship from the exchange rate, since the aggregated $p^E_{i,t}$ for all manufacturing sectors has a coefficient of correlation of 0.85 with the Bank of Canada's Commodity Price Index.

without controlling for age, skill level, education, or whether the positions are full- or part-time.[10] Using three different measures of labour could help identify whether exchange rate fluctuations impact the structure of the labour market, the labour force composition by class of workers, or the importance of the extensive versus the intensive (hours worked) margins.

The real effective exchange rate, s_t, is a weighted sum of the exchange rates between the Canadian dollar and the currencies of its major trading partners. The weights are linked to the share of each partner in Canada's international trade, and each nominal exchange rate is deflated by the country's CPI relative to Canada. An increase in s_t represents a real appreciation of the Canadian dollar.[11]

As a measure of world demand for Canadian manufactured goods, y_t^{all}, we use the simple sum aggregate of *G7* real GDPs evaluated at purchasing power parity provided by the OECD. Finally, the trade agreement dummies, $CUSFTA_t$ and $NAFTA_t$, take the value 1 starting in 1989 and 1994, respectively, while the dummy variable for the transition towards a floating exchange rate starts at 1976.[12]

The impact of exchange rate fluctuations on an industry's labour input should depend on its openness to trade, both in relation to exports (since currency depreciations facilitate sales in foreign markets) and to imports (so that the same depreciation reduces the competitiveness of foreign producers in domestic markets). To allow for this possibility, our empirical analysis carries out separate estimates for industries

[10] The authors thank Jean-Pierre Maynard from Statistics Canada for providing us with the jobs data. An earlier version of this work (Bruneau and Moran, 2012) used employment data from the Labour Force Survey (LFS) because the jobs data from KLEMS were not available at the time. Using a single data source (KLEMS) helps reduce possible biases arising from different variable definitions and measurement methods. It also allows us to extend our data coverage back to 1961.

[11] Our exchange rate data are from *Bruegel*, a Brussels-based research organization. The IMF, the OECD and the BIS also maintain measures of real effective exchange rates and use a variety of methods to deflate nominal exchange rates. See Lafrance, Osakwe, and St-Amant (1998) for a discussion.

[12] 1976 marks the year of the Jamaica Accord ratifying the end of the Bretton Woods System and ushering in freely floating exchange rates. A test for breaks using Hansen (1997), performed on our real exchange rate data, supports this choice of date for the switch from fixed to freely floating rates for the Canadian dollar. All the results are robust to the change of date from 1976 to 1973, which is the end of the Canadian participation in Bretton Woods, but not the end of Bretton Woods at the international level.

with high and low trade exposures. Our benchmark measure of trade exposure follows Dion (2000) and defines the *net trade exposure* (NTE) of an industry as: exports as a share of production, less imported output as a share of production, plus competing imports as a share of the domestic market. Statistics Canada's input-output tables for 2000 are used to calculate the NTE of each manufacturing industry. Industries with an NTE above the manufacturing sector average are classified as high-NTE industries, while below-average industries are classified as low-NTE industries. We also use an alternative classification based on *export intensity* (EI), with the export intensity of an industry defined as exports over production. Manufacturing industries with an EI above the manufacturing sector average are classified as high-EI sectors, while below-average industries are classified as low-EI sectors. Table B-1 in Appendix B presents the resulting classifications for the 20 manufacturing industries we study.

4 Econometric Methodology

Panel Data Estimation The recent popularity of panel data estimation largely arises from the robustness it provides relative to pure time-series models. As noted by Baltagi and Kao (2000), the econometrics of non-stationary panel data aims at combining the best of both worlds: the ability to account for non-stationary data from the time series and the increased data and power from the cross-section. For example, while undetected unit-root behaviour can lead to spurious inference in pure time-series models, regression estimates in panel data remain consistent because the information contained in the independent cross-section of the data leads to a stronger overall signal than in pure time-series cases (Kao, 1999; Phillips and Moon, 2000).

Although the OLS estimators of the cointegrated vectors are super consistent, correctly assessing the order of integration of the variables remains important to conduct inference, because the asymptotic distribution of panel estimators in the presence of unit roots and cointegration is non-standard, and the classic t-test statistic diverges at the same rate as in the time series (Kao and Chen, 1995; Pedroni, 1996; Kao and Chiang, 1999). In panel data models, the analysis is further complicated by the potential presence of heterogeneity, cross-sectional dependence and cross-sectional cointegration, and a proper limit theory must take into account the cross-section (N) and time (T) dimensions (Phillips and Moon, 1999).

Cross-Sectional Dependence Cross-sectional dependence (CSD) in macroeconomic panel data has received much attention in the emerging panel time-series literature. This type of correlation may arise from globally common shocks with heterogeneous impacts across countries, from local spatial or spillover effects, or it could be due to unobserved (or unobservable) common factors.[13]

Table 1: Cross-sectional Independence Tests

Variables	CD Statistics
$l_{i,t}$	9.4160^{***}
$h_{i,t}$	11.2070^{***}
$j_{i,t}$	10.4543^{***}

Note: The symbols *,** and *** indicate statistical significance of the statistics at the 10%, 5% and 1% level, respectively.

We use the Pesaran (2004) CD test to evaluate the cross-sectional dependence of our data, because this test has been shown to have good size and power for dynamic models with relatively small samples, and the test is robust to non-stationarity, parameter heterogeneity and structural breaks.[14] The test is based on the average of pairwise correlation coefficients of the residuals from the estimation of the cointegrating vectors (3), and the null hypothesis is the absence of cross-sectional dependence. The results of this test for each of the three measures of labour ($l_{i,t}$, $h_{i,t}$ and $j_{i,t}$) are presented in Table 1. The results reveal strong evidence against the null hypothesis of cross-sectional independence, and our empirical analysis below thus allows for CSD.

Unit Roots The first generation of panel unit-root tests is based on the hypothesis of cross-sectional independence (Harris and Tzavalis, 1999; Maddala and Wu, 1999; Hadri,

[13]For a detailed discussion of the topic within cross-country empirics, see Eberhardt and Teal (2011).

[14]See Moscone and Tosetti (2009) for a survey and application of existing *CSD* tests.

2000; Choi, 2001; Levin, Lin, and James Chu, 2002; Im, Pesaran, and Shin, 2003). This is an important limitation, since the application of such tests to series characterized by CSD leads to size distortions and low power (O'Connell, 1998; Banerjee, Marcellino, and Osbat, 2004; Strauss and Yigit, 2003). Unit-root testing for panels with CSD is the subject of an active literature, with two main solutions being suggested: the first relies on the factor structure approach (Choi, 2002; Bai and Ng, 2004; Moon and Perron, 2004; Pesaran, 2007),[15] while the second applies bootstrap algorithms to estimate the distribution of the statistic of interest conditional on the cross-sectional linkages (Chang, 2004; Smith, Leybourne, Kim, and Newbold, 2004; Cerrato and Sarantis, 2007; Palm, Smeekes, and Urbain, 2011).

To obtain results that are robust to both short- and long-run forms of CSD, we use the method proposed by Palm et al. (2011) (henceforth, the PSU tests). They consider block bootstrap versions of the pooled (Levin et al., 2002) and the group-mean (Im et al., 2003) unit root coefficients of a Dickey-Fuller (DF) test for panel data, denoted by τ_p and τ_{gm}, respectively, to test the null hypothesis of unit roots. These tests were originally proposed for a setting of no CSD beyond a common time effect. Asymptotic validity of the bootstrap tests is established in very general settings, including the case with dynamic interdependencies, the presence of common factors and cointegration across units. Asymptotic properties of the tests are derived for T going to infinity and N fixed, which is also desirable for our purpose.

Table 2 presents the results for panel unit-roots tests for the cross-sectional variables $l_{i,t}$, $h_{i,t}$, $j_{i,t}$, $w_{i,t}$, $p^K_{i,t}$, $p^{II}_{i,t}$, $p^E_{i,t}$, $p^M_{i,t}$, $p^S_{i,t}$ and $a_{i,t}$. The test is first conducted in levels and then in first differences.[16] The table shows that for most variables, strong evidence of $I(1)$ behaviour exists, with somewhat less conclusive results for the relative price of capital $p^K_{i,t}$.[17]

[15] See Gengenbach, Palm, and Urbain (2010) for a recent review of these methods.

[16] Not rejecting H_0 in levels suggests that the variable is at least $I(1)$; rejecting H_0 in first difference suggests the variable is at most $I(1)$.

[17] We performed a Pesaran (2007) CIPS* test with an optimal lag length chosen with the Akaike criterion to provide additional insight on the unit-root behaviour of the relative price of capital. The test results (not shown) show that evidence of $I(1)$ behaviour exists for $p^K_{i,t}$ for all three alternative

Table 2: PANEL UNIT-ROOT TESTS

Variables	Alternative hypotheses[a]					
	AR		*ARD*		*TS*	
	PSU Statistics[b]					
	τ_p	τ_{gm}	τ_p	τ_{gm}	τ_p	τ_{gm}
	In Levels					
$l_{i,t}$	0.0470	0.0689	-1.1476	-2.4546	-5.4440	-6.3920
$h_{i,t}$	0.0016	0.0008	-0.4627	-3.0922	-5.4450	-6.4035
$j_{i,t}$	0.0073	0.0051	-0.6282	-3.0429	-4.8269	-5.9161
$w_{i,t}$	-0.3943***	-0.7774***	-4.0488	-3.3268	-13.6534*	-10.4193
$p^K_{i,t}$	-0.5195	-1.8080	-14.6724***	-10.7183***	-19.5103***	-15.2089***
$p^{II}_{i,t}$	-0.0203	-0.0245	-2.4284	-5.3988	-5.8259	-8.3034
$p^E_{i,t}$	-0.2622**	-0.3453*	-0.3895	-0.5686	-3.3972	-3.4839
$p^M_{i,t}$	-0.0159	-0.0382	-1.8101	-5.0881	-6.2390	-9.0470
$p^S_{i,t}$	-0.0350	-0.0295	-1.5947	-3.3666	-3.2534	-4.3229
$a_{i,t}$	0.0609	0.0617	-2.4385	-3.5310	-10.5190*	-11.2905
	In First Differences					
$\Delta l_{i,t}$	-31.4591***	-33.0463***	-34.6833***	-35.9453***	-37.4751***	-39.0133***
$\Delta h_{i,t}$	-31.9202***	-33.2735***	-34.6962***	-35.6555***	-37.3214***	-38.5410***
$\Delta j_{i,t}$	-28.8352***	-29.9558***	-31.4239***	-32.0825***	-34.0882***	-35.0889***
$\Delta w_{i,t}$	-51.0093***	-37.7268***	-52.9262***	-41.4130***	-53.8325***	-42.2980***
$\Delta p^K_{i,t}$	-56.7900***	-48.6512***	-56.9293***	-48.9657***	-57.3164***	-49.6188***
$\Delta p^{II}_{i,t}$	-41.7332***	-39.8642***	-42.9191***	-41.7212***	-43.5098***	-42.8130***
$\Delta p^E_{i,t}$	-30.5355***	-28.5817***	-34.6579***	-32.8047***	-35.0634***	-33.1537***
$\Delta p^M_{i,t}$	-41.3257***	-40.0516***	-42.9329***	-42.4331***	-43.5269***	-43.5632***
$\Delta p^S_{i,t}$	-32.6551***	-28.1143***	-33.1951***	-28.5020***	-34.4936***	-29.4180***
$\Delta a_{i,t}$	-46.5930***	-44.5988***	-50.0814***	-47.8970***	-51.0197***	-49.1208***

Note: See note to Table 1.

[a]The alternative hypotheses are an autoregressive model (*AR*), an autoregressive model with drift (*ARD*) and a trend-stationary model (*TS*).

[b]We resample the residuals vector 1000 times with a block bootstrap scheme with a block length (B) equal to $1.75T^{1/3}$ to generate pseudodata with the null hypothesis of unit roots. The two test statistics are calculated for each bootstrap replication to get the approximated distribution of the statistics of interest.

We complement this with Table 3, which provides the results of the augmented Dickey-Fuller (ADF) unit-root tests for the aggregate variables s_t and y^{all}_t, which are not cross-sectional specific. The table reveals strong evidence of unit roots for these variables.[18]

hypotheses.

[18]Two other measures of the real effective exchange rate are discussed in Section 5.1. The ADF tests also indicate $I\,(1)$ behaviour for these two measures.

Table 3: Unit-Root Tests for Aggregate Variables

Variables	Alternative hypotheses[a]		
	AR	*ARD*	*TS*
	ADF Statistics[b]		
	In Levels		
s_t	-0.1320	-1.9616	-2.7813
y_t^{all}	2.7307	-5.0412***	-2.4194
	In First Differences		
Δs_t	-4.4161***	-4.3654***	-4.3113***
Δy_t^{all}	-2.0364**	-3.8626***	-5.0686***

Note: See note to Table 1.

[a]The alternative hypotheses are an autoregressive model (*AR*), an autoregressive model with drift (*ARD*) and a trend-stationary model (*TS*).

[b]Optimal lag length chosen with the Akaike criterion.

Cointegration Several panel cointegration tests have been suggested (McCoskey and Kao, 1998; Kao, 1999; Pedroni, 1999, 2001, 2004; Westerlund, 2005), which allow for various degrees of heterogeneity in the cointegrating coefficients. However, these tests are constructed so that the null and alternative hypotheses imply that all variables are either cointegrated or not cointegrated, with no allowance for the possibility that some variables are cointegrated and others are not. Moreover, it is often assumed that there exists at most one cointegrating relationship in the individual-specific models. System approaches to panel cointegration tests that do allow for more than one cointegrating relationship include the work of Larsson, Lyhagen, and Lothgren (2001) and Breitung (2005), who develop a likelihood-ratio test, and Maddala and Wu (1999), who use results in Fisher (1932) and propose an alternative approach to testing for cointegration in panel data by combining individual cross-sectional Johansen cointegration tests (Johansen, 1988, 1991) to obtain a test statistic for the full panel.

Recent contributions to the analysis of panel cointegration emphasize the importance of allowing for CSD, and the suggested solutions are similar to the panel unit-roots case.[19] To obtain results that are robust to CSD of various forms, we implement the

[19]See Di Iorio and Fachin (2009), Fachin (2007) and Westerlund and Edgerton (2007) for bootstrap

Table 4: Panel Cointegration Tests

Variables	Models[a]				
	H2	*H1**	*H1*	*H**	*H*
	$Johansen - Fisher$ Trace Statistics[b]				
$l_{i,t}$	276.3102***	276.3102***	265.9311***	267.8339***	226.4481*
$h_{i,t}$	276.3102***	276.3102***	262.4638***	266.7166***	229.6565*
$j_{i,t}$	276.3102***	276.3102***	259.6667***	262.9424***	222.9833

Note: See note to Table 1.

[a]The models described the form of the deterministic components of the VEC(q) model (see Johansen (1988, 1991)): no intercept or trend in the cointegrating relationships and no trend in the data (*H2*), intercepts in the cointegrating relationships and no trend in the data (*H1**), intercepts in the cointegrating relationships and linear trends in the data (*H1*), intercepts and linear trends in the cointegrating relationships and linear trends in the data (*H**), intercepts and linear trends in the cointegrating relationships and quadratic trends in the data (*H*).

[b]We resample the residuals vector 1000 times with an *iid* bootstrap scheme to generate pseudodata with the null hypothesis of no cointegration with an optimal lag order chosen by a Schwarz information criterion. The test statistics are calculated for each bootstrap replication to get the approximated distribution of the statistics of interest. The maximum eigenvalue test (not shown) was also calculated and yields the same conclusion.

Johansen-Fisher cointegration test (denoted λ), which is based on the combination of significance levels (p-value) of individual Johansen cointegration test statistics and has a χ^2 distribution under the cross-sectional independence hypothesis.[20] The presence of CSD implies that the tests are not independent; hence, the λ-statistic does not have a χ^2 distribution and must be approximated by bootstrap, as proposed in Maddala and Wu (1999). We use the algorithm developed in Swensen (2006) for time series, and we extend it to the panel case. Table 4 presents the test results for the null hypothesis of no cointegration against the alternative of a non-zero cointegration rank. It reveals strong statistical evidence in favour of cointegration for our panel. Moreover, tests conducted over all the possible cointegration ranks (not shown) point to a rank between 1 and 3, depending on the model and specification. Our empirical analysis below thus accounts for multiple cointegrating vectors.

approaches applied to single cointegrating vector testing.

[20]If the test statistics are continuous, the significance levels π_i, for $i = 1, \ldots, N$, are independent uniform $(0, 1)$ variables, and $-2 \ln \pi_i$ has a χ^2 distribution with 2 degrees of freedom. Using the additive property of the χ^2 variables, we get $\lambda = -2 \sum_{i=1}^{N} \ln \pi_i$ and λ has a χ^2 distribution with $2N$ degrees of freedom. See Maddala and Wu (1999) for more details.

Estimation Method Two popular techniques used to analyze a single-equation framework of cointegrated variables are the Fully Modified Ordinary Least Squares approach (Phillips and Hansen, 1990; Pedroni, 1996; Phillips and Moon, 1999) and the Dynamic Ordinary Least Squares approach (Saikkonen, 1991; Stock and Watson, 1993; Mark and Sul, 2003). Subsequent studies (Pedroni, 1996; Kao and Chiang, 1999; Phillips and Moon, 2000) show that these two techniques deliver unbiased estimators with standard normal distributions when applied to panel data. However, these estimators assume that explanatory variables are all $I(1)$ but are not cointegrated.[21] This drawback can be avoided by using system approaches.

System approaches to panel cointegration allowing for more than one cointegrating relationship include the work of Larsson et al. (2001), Groen and Kleibergen (2003) and Breitung (2005), who generalized the likelihood approach introduced in Pesaran et al. (1999). Breitung (2005) proposes a two-step estimation procedure that extends the Ahn and Reinsel (1990) and Engle and Yoo (1989) approach from the time series to the panel case. He considers a panel vector error-correction model set-up where only the cointegrating spaces are assumed to be identical for all cross-section members. In the first step of his procedure, the parameters (both long- and short-run) are estimated individually, and in the second step, the common cointegrating space is estimated in a pooled fashion. The resulting estimator is asymptotically efficient and normally distributed. Since results from Monte Carlo simulations in Breitung (2005) and Wagner and Hlouskova (2010) suggest that the two-step estimator has a good performance, we use this estimation method.[22] Statistical inference is then based on Driscoll-Kraay-Newey-West standard errors (Driscoll and Kraay, 1998).

We use a two-stage least-squares regression to estimate the industry-specific short-run

[21] If there is more than one cointegrating relationship, then the variance-covariance matrix of the residuals from the integrated process of the explanatory variables is singular and the results based on the asymptotic distribution is no longer valid.

[22] Even if there is more than one cointegrating relationship in the panel, we estimate only one relationship. This estimated relationship, in this case, still provides a consistent estimate of a cointegrating vector. Among the set of possible cointegrating relationships, the two-step estimator selects the relationship whose residuals are uncorrelated with any other $I(1)$ linear combinations of the explanatory variables (Hamilton, 1994).

relationship to control for the potential endogeneity of $w_{i,t}$. In the first stage, the relative price of labour is regressed on all predetermined and exogenous variables in the model. The predicted values obtained from this regression are then used in the second stage.[23]

5 Results

This section presents our estimation results. First, Section 5.1 presents our estimates of the (long-term) cointegrating vector (3) and then Section 5.2 discusses the dynamic (error-correcting) adjustment process (5). Throughout, we report results obtained using all 20 manufacturing industries, as well as high- and low-NTE subsets of these industries. An extensive sensitivity analysis is provided, which explores the robustness of our results to alternative measures for the labour input, for the real effective exchange rate, for openness to trade, and for the price of intermediate inputs. In all tables of results, estimates superscripted by *, ** or *** indicate significance at the 10 percent, 5 percent and 1 percent levels, respectively.

5.1 Long-Term Effects (Cointegrating Vectors)

Benchmark Results Table 5 presents our benchmark estimates of the cointegrating vector in expression (3). Most estimates are highly statistically significant and are consistent with our theoretical priors. Notably, the own-price elasticity (the effect of $w_{i,t}$ on labour input) is negative, while the impact of the price of capital ($p_{i,t}^{K}$) and that of the price of intermediate inputs ($p_{i,t}^{II}$) are positive, indicating substantial substitution between labour and other inputs. As suggested by theory, the coefficient of the real effective exchange rate is negative, indicating that an appreciation of the Canadian dollar is associated with a decrease in manufacturing's labour input,[24] while the

[23] To facilitate the presentation of our results, the estimated industry-specific coefficients reported in the various tables (coefficients on time dummies reported in Tables 5 to 11 and all the coefficients in Tables 12 to 14) are the mean-group estimates, an aggregation of industry-specific estimated coefficients via an equally weighted linear combination. However, all the simulations are conducted using the industry-specific estimated coefficients, not the mean-group estimates.

[24] Since we estimate a linear model, the relationship is symmetric. A depreciation of the real exchange rate then yields an increase in manufacturing labour input. This symmetry applies to all

impact of world GDP (y_t^{all}) is positive. The enactment of the two trade agreements has negative impacts on the labour input, a result compatible with earlier work (Gaston and Trefler, 1997; Beaulieu, 2000), indicating that trade liberalization has improved productivity but lowered employment in Canadian manufacturing industries. Finally, the transition towards a floating exchange rate regime is associated with a decrease in the labour input of manufacturing industries.

Table 5: COINTEGRATING VECTORS
Labour Input ($\ln l_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3642***	-0.2986**	-0.3204***
$\ln p_{i,t}^K$	0.0562***	0.1380***	-0.0266
$\ln p_{i,t}^{II}$	0.1899***	0.1605**	0.1981**
$\ln a_{i,t}$	0.1855	-0.0445	-0.1945
$\ln s_t$	-0.3007***	-0.3464***	-0.0224
$\ln y_t^{all}$	0.4785***	0.5259***	0.4286***
$CUSFTA_t$	-0.0529***	-0.0450***	-0.0818***
$NAFTA_t$	-0.1432***	-0.1573***	-0.0716**
FEX_t	-0.0957***	-0.0959***	-0.0533*

Note: Estimates of the cointegrating vector of expression (3) in the text, using the methods described in Breitung (2005) and Pesaran et al. (1999). The three columns depict estimates obtained for all, high- and low-NTE industries. The symbols *,** and *** indicate statistical significance of the coefficient at the 10%, 5% and 1% levels, respectively, using Driscoll-Kraay-Newey-West standard errors. Estimated coefficients and statistical inference for $CUSFTA_t$, $NAFTA_t$ and FEX_t are mean-group estimates.

The results in Table 5 are also economically significant. The estimate for the real exchange rate is -0.3007, indicating that a 10 percent real appreciation of the exchange rate is associated with a 3 percent long-term decrease in the labour input $l_{i,t}$. This impact is stronger for high-NTE industries (0.3464, or a decrease of 3.5 percent following a 10 percent real appreciation), while it is negligible and not statistically significant for low-NTE industries.

The impact of the price of labour $w_{i,t}$ is also substantial and, at -0.3642, is estimated to be of similar magnitude to that of the real exchange rate. The prices of other inputs (the price of capital $p_{i,t}^K$ and the price of intermediate inputs $p_{i,t}^{II}$) have positive impacts

results presented in this section.

of 0.0562 and 0.1899, respectively, suggesting that there is a substantial degree of substitution between labour and other inputs (see Appendix C for a discussion). The estimated impacts of $w_{i,t}$ and $p^{II}_{i,t}$ are of similar magnitude across industries, whereas for the price of capital $p^{K}_{i,t}$, the "all industries" average hides substantial differences between industries open to trade (a strong positive effect) and for those that are not (a negligible and not statistically significant impact).

The impact of world GDP (y^{all}_t) is also important, with the benchmark estimate suggesting a 0.48 percent long-run decrease in the labour input for each 1 percent decline in global demand for Canada's manufactured products. The effect again varies across openness to trade and is larger for high-NTE industries. The two trade agreements have had statistically and economically significant impacts, with the enactment of NAFTA being associated with a 15 percent decrease in the labour input for high-NTE industries.[25] Finally, Table 5 indicates that productivity has a positive, but not statistically significant, impact on the labour input. According to the model described in Appendix C, this could suggest that Canadian manufacturing firms operate in environments with relatively low substitution across different goods.[26]

Overall, Table 5 shows that exchange rate movements have statistically and economically significant long-run effects on the labour input of Canada's manufacturing firms, with a 10 percent real appreciation being associated with a 3 percent decrease in the labour input. In addition, input prices, global demand, and trade agreements also have substantial effects, and an industry's openness to trade is a key modifier to the magnitude of these impacts.

The impact of real exchange rate changes might be even stronger than suggested by the results in Table 5. If a real appreciation of the Canadian dollar makes imported

[25]The magnitude of the coefficient associated with NAFTA could, however, also signal the growing importance of China on the world manufacturing scene starting in the mid-1990s.

[26]An increase in productivity decreases marginal costs and, as a result, the price charged by the firm. The extent to which this price decrease results in a significant increase in demand – and a subsequent increase in labour demand – is governed by the elasticity of substitution across various products. If this elasticity is low, the coefficient on productivity could be negligible (see Appendix C).

capital more expensive and in turns leads to substitution away from capital and towards labour, an additional effect would be induced. However, the results in Table 5 suggest this added effect is likely to be small. Considering that across industries, roughly 1/6 of the capital input in our dataset is imported,[27] and that the estimated coefficient on the price of capital is relatively small (0.0562), the induced effect via imported capital (allowing for full pass-through of the appreciation into the Canadian price of imported capital[28]) would be $-(0.0562) \cdot 1/6$ or around -0.01, a much smaller figure than the direct effect of -0.3007 in Table 5.

Sensitivity Analysis To study the robustness of our results, we first repeat our estimation of the cointegrating vectors using alternative measures of the labour input. In this context, Tables 6 and 7 below present results obtained using hours worked ($h_{i,t}$) and jobs ($j_{i,t}$), respectively, instead of the labour input (l_{i_t}). Recall that hours worked $h_{i,t}$ is a simple sum of hours worked with no control for skill and experience (as is the case for l_{i_t}), while $j_{i,t}$ is the total number of jobs, again with no allowance for various work arrangements and experience differentials.

Table 6: Cointegrating Vectors
Hours Worked ($\ln h_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3604***	-0.3137**	-0.3053***
$\ln p_{i,t}^{K}$	0.0514**	0.1380***	-0.0381**
$\ln p_{i,t}^{II}$	0.2271***	0.1982***	0.2286**
$\ln a_{i,t}$	0.1967	-0.0529	-0.1077
$\ln s_t$	-0.3242***	-0.3541***	-0.0460
$\ln y_t^{all}$	0.3266***	0.3810***	0.2775***
$CUSFTA_t$	-0.0584***	-0.0422**	-0.1067***
$NAFTA_t$	-0.1698***	-0.1830***	-0.0936***
FEX_t	-0.0997***	-0.0961***	-0.0632*

Note: See note to Table 5.

Significant differences between the benchmark results of Table 5 and those arrived at

[27]In KLEMS, capital is a composite of machinery and equipment, structures, inventories and land inputs. Of those, only machinery and equipment has a significant imported component. The average imported component for the capital composite is estimated at 1/6 by Leung and Yuen (2005).

[28]Full pass-through is the hypothesis underlying the construction of the KLEMS data.

Table 7: Cointegrating Vectors
Jobs ($\ln j_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3133***	-0.2639*	-0.2598***
$\ln p^K_{i,t}$	0.0360	0.1287***	-0.0575***
$\ln p^{II}_{i,t}$	0.2869***	0.2228***	0.3146***
$\ln a_{i,t}$	0.2329	-0.0384	-0.1002
$\ln s_t$	-0.2691**	-0.2796***	-0.0198
$\ln y^{all}_t$	0.3481***	0.4044***	0.2967***
$CUSFTA_t$	-0.0963***	-0.0785***	-0.1487***
$NAFTA_t$	-0.1521***	-0.1656***	-0.0720**
FEX_t	-0.0831***	-0.0777***	-0.0475*

Note: See note to Table 5.

using hours worked (Table 6) or jobs (Table 7) would suggest that changes to real exchange rates have compositional effects on the labour mix or on the organization of the workweek, in addition to the aggregate effects described above. Overall, however, the results are qualitatively similar across the three tables. One quantitative difference does emerge, in Table 7, where the estimated coefficients on the real exchange rate are shown to be substantially smaller for jobs than those arrived at with the other two definitions of the labour input: -0.2691 relative to -0.3007 in the benchmark for all industries and -0.2796 relative to -0.3464 for high-NTE industries. Such a result suggests that a given appreciation of the real value of the Canadian dollar is associated with a smaller long-run decrease in jobs than in hours worked, indicating that both intensive and extensive margins respond to exchange rate movements. By contrast, the estimated magnitude of the impact for *CUSFTA* is larger for jobs than it was for $l_{i,t}$ and $h_{i,t}$. Notwithstanding these small differences, our results appear largely robust to the definition of the labour input.

Next, Table 8 assesses the importance of our measure of trade openness. Recall that our benchmark results are based on the measure in Dion (2000), which controls for the importance of exports as a share of production and for imports as a share of the domestic market. By contrast, Table 8 uses data on *Export Intensity* (EI) only (from

Industry Canada) to classify industries into high- and low-EI.[29]

Table 8: Cointegrating Vectors
Export Intensity

Variables	Industries		
	All	High EI	Low EI
$\ln w_{i,t}$	-0.3642***	-0.1427	-0.4352***
$\ln p_{i,t}^{K}$	0.0562***	0.0882***	0.0786
$\ln p_{i,t}^{II}$	0.1899***	-0.1742	0.3007***
$\ln a_{i,t}$	0.1855	-0.8884***	0.7227**
$\ln s_t$	-0.3007***	-0.4815***	-0.0844
$\ln y_t^{all}$	0.4785***	0.8180***	0.1746*
$CUSFTA_t$	-0.0529***	-0.0708***	-0.0310*
$NAFTA_t$	-0.1432***	-0.1455***	-0.1142***
FEX_t	-0.0957***	-0.1088***	-0.0646**

Note: See note to Table 5.

This modification has important consequences for the magnitude and statistical significance of many estimates. First, the impact of the real exchange rate for industries highly open to trade is now -0.4815, 50 percent stronger than -0.3007, its "all industries" counterpart (the coefficient for industries not open to trade remains low and not statistically significant). This suggests that it is for exporting industries, more than for industries affected by trade via imports, that appreciation and depreciation cycles in the real value of the Canadian dollar have important impacts. Similarly, the influence of worldwide product demand (the impact of y_t^{all}) is almost double in industries highly open to trade, relative to their "all industries" benchmark. Overall, the results in Table 8 support benchmark estimates but single out exports as the key marker across which movements in the exchange rate and product demand affect the labour input of Canada's manufacturers.

Continuing our robustness analysis, Tables 9 and 10 analyze alternative measures for the exchange rate. First, Table 9 presents results obtained using *nominal* effective exchange rates. Since movements in real exchange rates are often considered to be dominated by nominal rate changes (and only very gradual relative price adjustments),

[29]The first column of Table 8, for all industries, naturally reproduces the benchmark results of Table 5.

these might be sufficient to measure the actual ability of domestic producers to export abroad profitably. By contrast, Table 10 retains the idea of deflating nominal exchange rates, but uses relative unit labour costs (RULC) to do so. This deflating strategy follows a body of literature arguing that using unit labour costs to deflate exchange rates is a suitable method to accurately capture Canada's ability to sell abroad profitably (Lafrance et al., 1998).

Table 9: COINTEGRATING VECTORS
Nominal EER

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3649***	-0.2642*	-0.3434***
$\ln p_{i,t}^{K}$	0.0549***	0.1326***	-0.0248
$\ln p_{i,t}^{II}$	0.1666***	0.1273*	0.1889**
$\ln a_{i,t}$	0.1273	-0.1414	-0.1340
$\ln s_t$	-0.4375***	-0.5052***	-0.1141
$\ln y_t^{all}$	0.6107***	0.6629***	0.4784***
$CUSFTA_t$	-0.0426***	-0.0357**	-0.0806***
$NAFTA_t$	-0.1182***	-0.1216***	-0.0813***
FEX_t	-0.1145***	-0.1116***	-0.0689**

Note: See note to Table 5.

Alternative measures of exchange rates modify some of the quantitative results. Notably, the estimated coefficients on exchange rates increase in magnitude when nominal effective exchange rates are used (Table 9), but this magnitude is then decreased when unit labour costs are used (Table 10). The pattern from Table 5, by which openness to trade increased this coefficient for high-NTE industries and reduced it to small, not statistically significant, numbers for low-NTE industries can also be seen in Tables 9 and 10. The impact of worldwide product demand (y_t^{all}) similarly increases in Table 9 but is reduced in Table 10, relative to the benchmark results in Table 5.

Finally, Table 11 assesses a decomposition of the price of intermediate goods $p_{i,t}^{II}$ into the relative price of energy $p_{i,t}^{E}$, of materials $p_{i,t}^{M}$ and of services $p_{i,t}^{S}$. Interestingly, this has the effect of reducing both the economic and statistical significance of the exchange rate. Since, at the same time, the price of energy is found to be both negative and very substantial economically, this result is probably explained by the

Table 10: COINTEGRATING VECTORS
Real EER - RULC

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3898***	-0.3236***	-0.3346***
$\ln p^K_{i,t}$	0.0752***	0.1524***	-0.0055
$\ln p^{II}_{i,t}$	0.1238***	0.0256	0.1831**
$\ln a_{i,t}$	0.3972***	0.1945	-0.0717
$\ln s_t$	-0.1383***	-0.1405*	-0.0029
$\ln y^{all}_t$	0.1797***	0.2207***	0.2476***
$CUSFTA_t$	0.0229**	0.0295**	-0.0384*
$NAFTA_t$	-0.0699***	-0.0771***	-0.0470**
FEX_t	-0.0316**	-0.0378**	-0.0166

Note: See note to Table 5.

high correlation between energy prices and the exchange rate of the Canadian dollar over the past two decades.

Table 11: COINTEGRATING VECTORS
Disaggregated Prices of Intermediated Inputs

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.2672***	-0.2806**	-0.2082***
$\ln p^K_{i,t}$	0.0451**	0.1223***	-0.0334**
$\ln p^E_{i,t}$	-0.2502***	-0.2728***	-0.1218*
$\ln p^M_{i,t}$	0.1765***	0.1300**	0.1899***
$\ln p^S_{i,t}$	-0.0420	0.0058	-0.0908
$\ln a_{i,t}$	0.2769*	0.1274	-0.2072
$\ln s_t$	-0.1331*	-0.1203	0.0295
$\ln y^{all}_t$	0.5786***	0.6638***	0.4577***
$CUSFTA_t$	-0.0768***	-0.0761***	-0.0825***
$NAFTA_t$	-0.1183***	-0.1226***	-0.0647**
FEX_t	0.0079	0.0185	-0.0138

Note: See note to Table 5.

In summary, our estimates of the cointegrating relationship (3) reveal important and robust findings: exchange rates and worldwide demand for Canadian products exert powerful long-run influences on the labour input of manufacturing firms, and these effects are stronger for industries that are more open to trade, particularly for exporters. Further, the enactment of two major trade agreements had an important negative effect on labour inputs. Finally, we find evidence that substantial levels of substitution exist between labour and other inputs, so that increases in the price of capital and intermediary inputs lead to increases in the labour input of manufacturing firms. The next subsection explores the characteristics of the dynamic adjustment to these long-run properties.

5.2 Dynamic Adjustment (Error-Correcting Mechanism)

This subsection analyzes the adjustment towards the long-term cointegrating vector in (3). To this end, equation (5) is estimated via a two-stage least-squares framework that aims at correcting for possible problems of endogeneity between wages and the labour input. A general-to-specific strategy is used to establish the number of lags p needed in (5), and the exchange rate is the only variable for which lagged values appear in a statistically significant manner. As a consequence, only the current values of wages, prices, productivity and world output appear in the three tables of results below, whereas for the exchange rate, both current and lagged values are present.[30] Estimation results are provided in Tables 12-14 for the labour input, hours worked and jobs, respectively.

The first result of interest concerns the speed of adjustment towards the long-run labour input, governed by the estimate labeled $EC_{i,t}$ in the tables. Table 12 shows that, in the benchmark case, this parameter equals -0.1436, indicating that about 15 percent of the gap between the targeted (frictionless) labour input and its actual value is closed every period-year. This 15 percent annual gap adjustment is fairly stable across industry types (high- or low-NTE) and for the alternative definitions of labour in Table 13 and Table 14. These results suggest the presence of significant costs of adjusting labour and a very gradual progression, with a half-life between 4 and 5 years, towards the target.

The second group of results of interest taken from Tables 12 to 14 concerns the influence of the exchange rate. As the tables indicate, the lagged values of the (growth in) exchange rates exert an important influence on the labour input of Canadian

[30] By construction, the first lag of the labour input enters the dynamic adjustment of (5).

Table 12: Short-term Dynamics
Labour Input $(\Delta \ln l_{i,t})$

Variables	Industries		
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1436***	-0.1527***	-0.1363***
$\Delta \ln l_{i,t-1}$	0.1120***	0.1124**	0.1306**
$\Delta \ln w_{i,t}$	-0.0466	-0.0684	0.0278
$\Delta \ln p^K_{i,t}$	0.0773***	0.0813***	0.0649***
$\Delta \ln p^{II}_{i,t}$	0.0751	0.1070	-0.0267
$\Delta \ln a_{i,t}$	-0.8597***	-0.4225***	-1.7385***
$\Delta \ln s_t$	0.0328	0.0883**	-0.0715
$\Delta \ln s_{t-1}$	-0.2315***	-0.3000***	-0.0654
$\Delta \ln y^{all}_t$	1.2277***	1.3839***	0.7615***

Note: Estimates of the short-term relationship (5) in the text. The three columns depict estimates obtained for all, high- and low-NTE industries. The symbols *,** and *** indicate statistical significance of the coefficient at the 10%, 5% and 1% levels, respectively. Estimated coefficients and statistical inference for all variables are mean-group estimates.

manufacturing firms.[31] These results suggest that during the transition towards its long-run target, the labour input of Canadian manufacturing firms is subjected to sizeable fluctuations associated with lagged movements in exchange rates. The numerical estimate suggests that, along this path, a 10 percent appreciation of the Canadian currency would cause (ultimately transitory) decreases in the labour input by a factor of between 2 percent and 2.5 percent. Decomposing industries into high- and low-NTE shows that this effect is particularly present for high-NTE industries and not statistically significant for low-NTE ones. It is interesting to note that only the lagged values of Δs_t have a statistically significant impact: exchange rate movements appear to have only a lagged protracted impact on the labour input. Table 14 also shows that the exchange rate affects both the intensive and the extensive margins: industries tend to decrease not only the total number of jobs, but also the average number of hours worked for remaining jobs.

Third, the tables reveal that multifactor productivity $a_{i,t}$ also affects the dynamic adjustment trajectory. Specifically, Tables 12 to 14 reveal that a 1 percent increase

[31] Recall that this effect is separate from the one arising when the *level* of the exchange rate affects the long-run (frictionless) labour input.

Table 13: Short-term Dynamics
Hours Worked ($\Delta \ln h_{i,t}$)

Variables		Industries	
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1276***	-0.1349***	-0.1338***
$\Delta \ln l_{i,t-1}$	0.1160***	0.1219***	0.1304**
$\Delta \ln w_{i,t}$	-0.0576	-0.0743	0.0213
$\Delta \ln p^{K}_{i,t}$	0.0735***	0.0810***	0.0553***
$\Delta \ln p^{II}_{i,t}$	0.0597	0.0926	-0.0582
$\Delta \ln a_{i,t}$	-0.8554***	-0.4308***	-1.6960***
$\Delta \ln s_{t}$	0.0219	0.0643	-0.0633
$\Delta \ln s_{t-1}$	-0.2445***	-0.3105***	-0.0791
$\Delta \ln y^{all}_{t}$	1.2606***	1.4110***	0.7954***

Note: See note to Table 12.

Table 14: Short-term Dynamics
Jobs ($\Delta \ln j_{i,t}$)

Variables		Industries	
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1265***	-0.1241***	-0.1664***
$\Delta \ln l_{i,t-1}$	0.1949***	0.2013***	0.2048***
$\Delta \ln w_{i,t}$	-0.0945**	-0.1448***	0.0522
$\Delta \ln p^{K}_{i,t}$	0.0503***	0.0538***	0.0399**
$\Delta \ln p^{II}_{i,t}$	0.0635	0.1086	-0.0735
$\Delta \ln a_{i,t}$	-0.5864***	-0.1958**	-1.3108***
$\Delta \ln s_{t}$	0.0123	0.0603	-0.0817
$\Delta \ln s_{t-1}$	-0.2096***	-0.2627***	-0.0788
$\Delta \ln y^{all}_{t}$	1.1357***	1.3098***	0.6142***

Note: See note to Table 12.

in productivity reduces labour by close to 1 percent (0.86) for the measures of labour and hours worked (Tables 12 and 13) but by less for jobs (Table 14). Recall that multifactor productivity was found to have a positive, but not statistically significant, influence on the long-run labour input. Its impact on the short-term labour input may suggest institutional aspects that make it hard for firms to quickly expand production when productivity increases and lead them to service the same markets with a reduced labour input. Finally, Tables 12 to 14 show that world output also has an important effect on the dynamic adjustment towards the long-run equilibrium, in addition to the impact it had on the long-run level. The tables reveal that this impact is large, more than one for one, and is especially important for high-NTE industries.

Figure 2 provides a useful way to visualize the value added of the dynamic adjustment component of our estimation strategy. Panel (a) of the figure plots observed values for labour against the value predicted by the long-run relationship (3) only, without allowing for the dynamic adjustment (5), while Panel (b) depicts the observed and predicted series according to the full model (5), which accounts for both the estimated long-run relationship and the dynamic adjustment towards that long-run relationship. The figure shows that the full model, which includes the dynamic adjustment components, is better able to fit both the levels and the timing of the swings in labour input over our sample.[32]

6 Conclusion

We present evidence that the boom-bust cycles experienced in the labour market of Canada's manufacturing industries over the past five decades are strongly connected to fluctuations in the exchange rate of the Canadian dollar. Our econometric strategy employs panel data estimation techniques and carefully controls for the unit root, cointegration and cross-sectional dependence found in the data. Our results suggest that a 10 percent appreciation of the Canadian dollar can decrease hours worked and jobs by around 3 percent and that this effect occurs relatively slowly, with about 15 percent of the gap between the actual and targeted labour input being closed every year. These results are significantly stronger in industries with above-average net trade exposure. We also provide evidence that the enactment of two major trade agreements in 1989 and 1994 had sizeable negative impacts on the number of hours worked and the number of jobs in Canadian manufacturing industries. These results are timely, as the more recent period of depreciation of the currency has led to conjectures about

[32] The figure plots the observed and predicted values of the labour input in the all-industries case. Predicted labour is generated recursively by the model for each year, with the initial year in our sample (1961) serving as the initial condition. This recursive method implies that the actual lagged labour input is never used to generate the predictions. The root-mean-square error is reduced by close to 28 percent by using the full model.

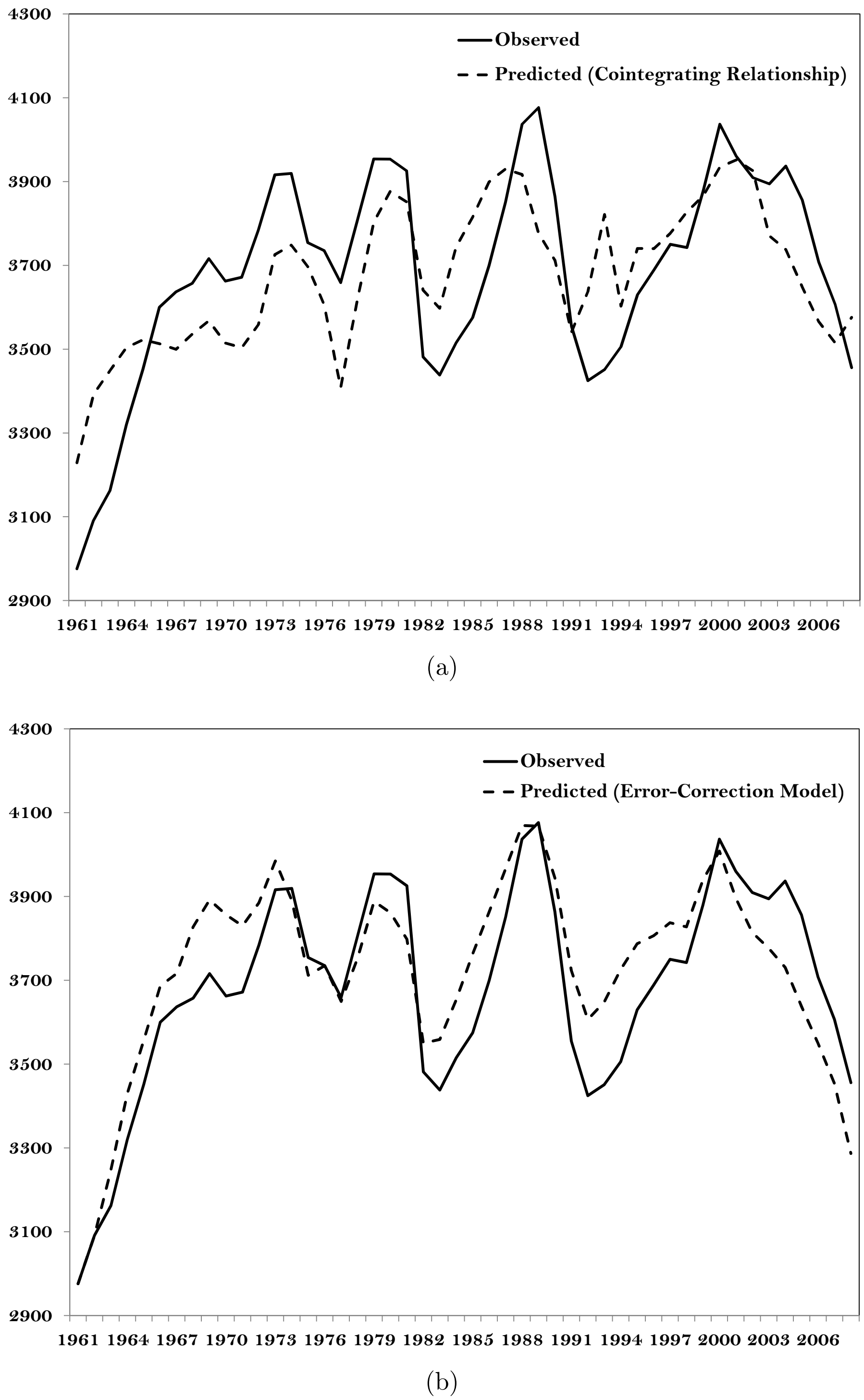

Figure 2: Hours Worked Dynamic In-Sample Predictions for (a) Cointegrating (Long-run) Relationship only and for (b) Error-correction Model

whether manufacturing in Canada will rebound.

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Appendices

A Definitions and Data Sources

A.1 Industry-Specific Data - *KLEMS*

Labour input ($l_{i,t}$)

1961 to 2008 data

Labour inputs, by manufacturing industry at the NAICS 3-digit (industry) level. This index is obtained by chained Fisher aggregation of hours worked across all workers, classified by education, work experience and class of workers (paid workers, as opposed to self-employed and unpaid family workers) using hourly compensation as weights.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

Hours worked ($h_{i,t}$)

1961 to 2008 data

Hours worked, by manufacturing industry at the NAICS 3-digit level. The number of hours worked in all jobs is the number of all jobs times the annual average hours worked in all jobs. According to the retained definition, hours worked means the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers retain their positions. On the other hand, time lost due to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs is not included in total hours worked.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

Jobs ($j_{i,t}$)

1961 to 2008 data

Total number of jobs (full- and part-time), by manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada, Internal Calculations

Relative price of labour $(w_{i,t})$

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the compensation index and the Fisher volume index of labour, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level. Labour compensation includes all payments in cash or in kind made by domestic producers to workers for services rendered, i.e., the total payroll. It includes the salaries and supplementary labour income of paid workers, plus an imputed labour income for self-employed workers. The Industrial Product Price Index (IPPI) measures price changes for major commodities sold by manufacturers in Canada. The prices collected are for goods sold at the factory gate. As a result, the prices covered by the IPPI are those received by the producer rather than those paid by the purchaser. They exclude all indirect taxes, such as sales taxes and tariffs, because this money is not paid to production factors (labour, capital, other inputs), or profit. They also exclude any transportation service performed by a common carrier beyond the factory gate and any distribution services performed by the retail or wholesale trade industries.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of capital $(p^K_{i,t})$

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the capital cost index and the Fisher volume index of capital inputs, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level. Capital costs represents the surplus profits, depreciation, rent and net interest intended as compensation to the owners of capital. It is calculated as the nominal GDP at basic prices minus labour compensation.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of intermediate inputs ($p^{II}_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the intermediate inputs cost index and the Fisher volume index of intermediate inputs, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of energy ($p^{E}_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the energy cost index and the Fisher volume index of energy inputs, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of materials ($p^{M}_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the materials cost index and the Fisher volume index of material inputs, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of services ($p^{S}_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the cost of services index and the Fisher volume index of service inputs, deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Multifactor productivity ($a_{i,t}$)

1961 to 2008 data

Multifactor productivity, based on gross output, measures the efficiency with which all inputs, including capital, labour and intermediate inputs, are used in production. It is the ratio of real gross output to combined units of all inputs.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

A.2 Aggregate Data

Real effective exchange rate (s_t)

1961 to 2008 data

The nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade and deflated by the pairwise relative CPIs of the countries.

Source: Bruegel (http://www.bruegel.org/datasets/real-effective-exchange-rates-for-178-countries-a-new-database/)

Real effective exchange rate (first alternative: Unit Labour Costs) (s_t)

1971 to 2008 data

The nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade and deflated by the pairwise relative unit labour costs in those countries.

Source: OECD (http://stats.oecd.org/index.aspx)

Real effective exchange rate (second alternative: No Deflating for Prices) (s_t)

1961 to 2008 data

The nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade. Extracted from a database of real exchange rates for 178 countries provided by Bruegel in Brussels.

Source: Bruegel (http://www.bruegel.org/datasets/real-effective-exchange-rates-for-178-

countries-a-new-database/)

G7 real gross domestic product (y_t^{all})

1961 to 2008 data

Simple sum aggregate of $G7$ real GDPs evaluated at PPP.

Source: OECD (OECD.StatExtracts (http://stats.oecd.org/). Subject: "B1 GE: Gross domestic product - expenditure approach"; measure: "VIXOBSA: Volume index, OECD reference year, seasonally adjusted".)

CUSFTA dummy ($CUSFTA_t$)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning in and after 1989 and 0 before 1989, to signal the enactment of the Canada-U.S. Free Trade Agreement.

NAFTA dummy ($NAFTA_t$)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning in and after 1994 and 0 before 1994, to signal the enactment of the North-American Free Trade Agreement.

FEX dummy (FEX_t)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning in and after 1976, to signal the completion of the transition towards a freely floating exchange rate between Canada's currency and that of its trading partners. Note: 1976 is the year of the Jamaica Accord, which ratified the end of the Bretton-Woods system of fixed exchange rates. The presence of a break at this date is supported by a Hansen (1997) test.

B Industry Classification by Net Exposure to International Trade

Table B-1: Industries by Net Trade Exposure and Export Intensity

NAICS	Manufacturing Industries	NTE	EI
311	Food	Low	Low
312	Beverage and tobacco product	Low	Low
313 and 314	Textile mills and Textile product mills	High	Low
315	Clothing	High	Low
316	Leather and allied product	High	Low
321	Wood product	High	High
322	Paper	High	High
323	Printing and related support activities	Low	Low
324	Petroleum and coal product	Low	Low
325	Chemical	High	High
326	Plastics and rubber product	High	High
327	Non-metallic mineral product	Low	Low
331	Primary metals	Low	High
332	Fabricated metal product	High	Low
333	Machinery	High	High
334	Computer and electronic product	High	High
335	Electrical equipment, appliance and component	High	High
336	Transportation equipment	High	High
337	Furniture and related product	High	High
339	Miscellaneous	High	Low

C Derivation of the Labour Input Demand

Frictionless (*Long-Run*) Labour Demand

Consider the typical manufacturing firm j in industry i. Assume this firm produces $y_{i,j,t}$ using the following CES production function using labour ($l^*_{i,j,t}$) and capital ($k_{i,j,t}$) inputs:

$$y_{i,j,t} = a_{i,t}\left[{l^*_{i,j,t}}^{\frac{\alpha-1}{\alpha}} + \kappa^{\frac{1}{\alpha}} {k_{i,j,t}}^{\frac{\alpha-1}{\alpha}}\right]^{\frac{\alpha}{\alpha-1}}, \tag{6}$$

where $a_{i,t}$ is (industry-specific) multifactor productivity and α is the elasticity of substitution between the two inputs.

Denote the industry-specific prices of labour and capital by $w_{i,t}$ and $p^k_{i,t}$, respectively, so that total costs for the firm is $tc_{i,j,t} = w_{i,t}l^*_{i,j,t} + p^k_{i,t}k_{i,j,t}$. Minimizing total costs $tc_{i,j,t}$ under the constraint of producing a given level of output yields the following cost curve:

$$tc_{i,j,t} = mc_{i,t}y_{i,j,t},$$

where $y_{i,j,t}$ is the chosen level of production, and marginal cost $mc_{i,t}$ is common across firms of the same industry:

$$mc_{i,t} = \frac{\left[{w_{i,t}}^{1-\alpha} + \kappa {p^k_{i,t}}^{1-\alpha}\right]^{\frac{1}{1-\alpha}}}{a_{i,t}}. \tag{7}$$

In addition, the following labour input demand obtains from the cost-minimization problem:

$$l^*_{i,j,t} = y_{i,j,t}{mc_{i,t}}^{\alpha}{a_{i,t}}^{\alpha-1}{w_{i,t}}^{-\alpha}. \tag{8}$$

Next, let firm j face the following constant-elasticity demand for its product, originating from both domestic and foreign markets:

$$y^d_{i,j,t} = \left(\frac{P_{i,j,t}}{P_t}\right)^{-\theta} Y_t + \chi_{i,t}\left(\frac{P_{i,j,t}E_t}{P^*_t}\right)^{-\theta} Y^*_t, \tag{9}$$

where $P_{i,j,t}$ is the (domestic currency) price charged by the firm, E_t is the nominal exchange rate, P_t and P_t^* are the general price levels in the domestic and the foreign country, respectively, Y_t and Y_t^* are measures of general economic activity in these two markets, and θ is the price-elasticity of demand. The term $\chi_{i,t}$ denotes industry-specific shifts in demand, perhaps arising from new trade agreements. Denoting the relative price of the firm's product as $p_{i,j,t} \equiv P_{i,j,t}/P_t$ and the real exchange rate by $s_t \equiv E_t P_t / P_t^*$, one can rewrite (9) as

$$y_{i,j,t}^d = {p_{i,j,t}}^{-\theta} \left(Y_t + \chi_{i,t} s_t Y_t^* \right) = {p_{i,j,t}}^{-\theta} x_{i,t}, \tag{10}$$

where we have defined the product-demand shifter $x_{i,t} \equiv (Y_t + \chi_{i,t} s_t Y_t^*)$.

Profit maximization is then the following problem:

$$\max_{p_{i,j,t}} p_{i,j,t} y_{i,j,t} - mc_{i,t} y_{i,j,t},$$

subject to (10). The solution to this problem is to set prices at a constant markup over marginal cost for all firms, thus allowing us to drop the index j from its expression:

$$p_{i,t} = \frac{\theta}{\theta - 1} mc_{i,t} = \mu \, mc_{i,t}.$$

Using (10) then allows us to back out the (common) product demand at the optimal price:

$$y_{i,t} = \left(\mu mc_{i,t} \right)^{-\theta} x_{i,t},$$

and, using (8), the labour input necessary to satisfy this demand:

$$l_{i,t}^* = \mu^{-\theta} {mc_{i,t}}^{\alpha - \theta} x_{i,t} {a_{i,t}}^{\alpha - 1} {w_{i,t}}^{-\alpha}. \tag{11}$$

Finally, using (7) to replace marginal costs and taking a first-order approximation yields the labour demand equation, expressed in log-deviations from steady-state:

$$\ln l_{i,t}^{*} = -\left(\left(1 - sh^{l}\right)\alpha + sh^{l}\theta\right)\ln w_{i,t} + (\alpha - \theta)\, sh^{k} \ln p_{i,t}^{k} + (\theta - 1)\ln a_{i,t} + \ln x_{i,t}, \quad (12)$$

with sh^l the labour share of total costs and sh^k the capital share. This recovers the frictionless labour demand (3) in the text and defines the cointegrating relationship we estimate. Notice that the coefficient on $\ln w_{i,t}$ is unambiguously negative but that the sign on capital's coefficient, $(\alpha - \theta)sh^k$ depends on the value of the elasticity of substitution between inputs α.[33] Further, the impact of technology is positive, with a magnitude equal to $\theta - 1$.[34]

Note that equation (12) represents only the demand side of labour market equilibrium in each manufacturing industry. Nevertheless, interpreting it as a cointegration relationship allows us to estimate it without creating any econometric problems due to endogeneity.

Dynamic Adjustment Towards the Frictionless Labour Demand

Now consider quadratic adjustment costs to labour that prevent a frictionless labour input choice (Nickell, 1987; Hamermesh and Pfann, 1996). Profit maximization becomes

$$\max_{\{l_{i,t},k_{i,t}\}} E_0 \sum_{t=0}^{\infty} \delta^t \left[p_{i,t}y_{i,t} - w_{i,t}l_{i,t} - p_{i,t}^{k}k_{i,t} - w_{i,t}\frac{b}{2}(l_{i,t} - l_{i,t-1})^2 \right], \quad (13)$$

subject to (10) and (6), where δ is the discount factor applied to future dividends and b indexes the extent of the adjustment costs. Nickell (1987) shows that a first-order

[33] An increase in p^k has two opposite effects on labour. On the one hand, it raises marginal costs which, through the price-setting rule, leads to price increases and thus declines in product demand, which implies a decrease in the labour input. On the other hand, it leads firms to substitute away from capital towards labour for a given production level. This latter effect dominates when $\alpha > \theta$; thus, the labour input increases.

[34] A rise in productivity decreases marginal costs and thus prices, again through the price-setting rule. The extent to which this increases product demand – and therefore labour input – depends on θ. In environments where θ is low (i.e., products have relatively few substitutes), one would expect the impact of productivity on labour demand to be low.

approximate solution to (13) has the following partial-adjustment process:

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu)(1-\delta g \nu) E_t \left[\sum_{\tau=0}^{\infty} (\delta g \nu)^{\tau} \ln l^*_{i,t+\tau} \right], \tag{14}$$

where ν depends on the adjustment costs, g is the long-term real wage growth trend and $l^*_{i,t}$ is the frictionless ($b = 0$) labour demand from (12). Labour demand for the typical firm in industry i thus follows a partial-adjustment process that gradually attains a target equal to a geometric sum of the future expected values of $l^*_{i,t}$, with the speed of adjustment $1-\nu$ depending on the severity of the adjustment costs. If changes in the variables affecting $l^*_{i,t}$ are largely permanent (a hypothesis validated by our unit-root analysis), (14) simplifies to

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu) \ln l^*_{i,t},$$

as in the text.