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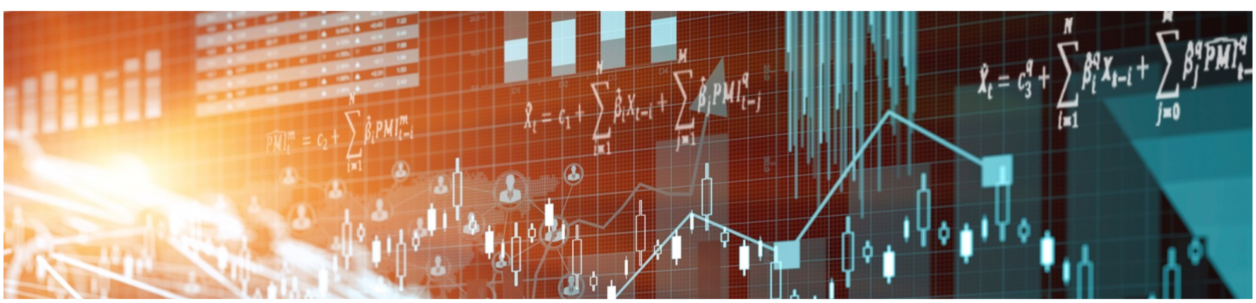
An Improved Equation for Predicting Canadian Non-Commodity Exports



by Patrick Alexander, Jean-Philippe Cayen and Alex Proulx

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Patrick Alexander, Jean-Philippe Cayen and Alex Proulx

Canadian Economic Analysis Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
palexander@bankofcanada.ca
jcayen@bankofcanada.ca
aproulx@bankofcanada.ca

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Abstract

We estimate two new equations for Canadian non-commodity exports (NCX) that incorporate three important changes relative to the current equation used at the Bank of Canada. First, we develop two new foreign activity measures (FAMs), which add new components to the FAM currently used at the Bank of Canada. The first measure adds US exports and US government expenditures, and the second adds US industrial production. These new FAMs calibrate the weights on the various components based on the 2014 World Input-Ouput Database to avoid the instability problem that arises when the equations are estimated. Second, we add a new variable to the equations, the trend of Canada's manufacturing share of output, to control for structural or competitiveness factors that affect Canada's global import market share. Third, the relative price of exports is determined by a new measure of the Canadian real effective exchange rate developed by Barnett, Charbonneau and Poulin-Bellisle (2016). We find that the new equations improve the in-sample fit and the out-of-sample forecast accuracy relative to the current equation specified in "LENS," a forecasting model used at the Bank of Canada.

Bank topics: Balance of payments and components; Exchange rates; International topics
JEL codes: F10, F14, F17

Résumé

Nous estimons deux nouvelles équations des exportations hors produits de base qui incorporent trois changements importants par rapport à l'équation qui est présentement utilisée à la Banque. Premièrement, nous avons mis au point deux nouvelles mesures de l'activité étrangère (« MAE ») qui ajoutent de nouvelles composantes à la MAE qu'utilise la Banque. La première mesure ajoute les exportations et les dépenses publiques des États-Unis, et la seconde, la production industrielle américaine. Les coefficients de pondération affectés aux diverses composantes de chaque MAE sont calibrés d'après les données des tableaux internationaux des entrées-sorties pour 2014 afin d'éviter les problèmes d'instabilité qui se produisent lorsque ces coefficients sont estimés. Deuxièmement, nous avons inclus une nouvelle variable aux équations, la part tendancielle de la production manufacturière au Canada, afin de rendre compte des facteurs qui influent sur la part du Canada dans le marché mondial des importations, qu'il s'agisse de facteurs structurels ou de facteurs liés à la compétitivité. Troisièmement, le prix relatif des exportations est déterminé à partir d'un nouvel indice du taux de change effectif du dollar canadien construit par Barnett, Charbonneau et Poulin-Bellisle (2016). Dans l'ensemble, ces nouvelles équations améliorent l'adéquation statistique à l'intérieur de l'échantillon et offrent de meilleures prévisions hors échantillon comparativement à l'équation des exportations hors produits de base actuellement spécifiée dans le modèle « LENS » utilisé à la Banque.

Sujets : Balance des paiements et composantes; Taux de change; Questions internationales
Codes JEL : F10, F14, F17

Section 1 | Introduction

Non-commodity exports (NCX) have played a key role in Canadian economic growth. The Bank's current models used to forecast NCX rely significantly on an estimate of foreign demand for Canadian firms' goods and services. We find that, while these equations do very well to explain the evolution of NCX before 2011, they have significantly overpredicted it in recent years. As a result, Canadian NCX have been consistently weaker than Bank of Canada staff expected over this period, suggesting that additional factors unaccounted for by our current models are at play (Guénette et al. 2016).

In this paper, we develop a quantitative model that is better designed to capture the drivers of NCX. In particular, we revisit the specification of the foreign activity measure (FAM) used at the Bank of Canada to proxy foreign demand and explore new variables to control for competitiveness and structural factors.

Current staff equations for Canadian NCX include a mix of price and demand indicators as explanatory variables. We find that these equations appear to have failed to account for the loss of competitiveness and the reduction in Canadian export capacity over time. In addition, we find that the weights for the components of the Bank's foreign activity measure (FAM), the demand proxy developed by Morel (2012), are sensitive to the estimation period used and change significantly after adding or subtracting a few years of observations.

To address these concerns, we estimate two new NCX equations that incorporate three important changes relative to the model developed by Morel (2012). First, to improve the model fit, we have added a new variable to the equations, the trend of Canada's manufacturing share of output that controls for structural or competitiveness factors that affect Canada's global import market share. Second, the relative price of exports is determined by a new measure of Canadian real effective exchange rate developed by Barnett, Charbonneau and Poulin-Bellisle (2016). Third, to avoid instability in the estimated demand component weights of the FAM, the new measure calibrates the parameters based on 2014 World Input-Output Tables and includes several demand variables in addition to Morel's (2012) original set.

We find that these adjustments greatly improve model properties and forecast accuracy. Accordingly, the work presented in this paper will be incorporated in the set of tools used at the Bank to forecast Canadian exports.[1]

[1] This work is part of a broad agenda that aims to improve our forecasting tools to predict Canadian exports. While our model uses the same framework as the Bank's current model, Bank staff have also examined different

The remainder of this paper is organized as follows. Section 2 provides a discussion of related literature. Section 3 describes the new equation, while Section 4 shows the results. Section 5 concludes.

Section 2 | Literature Review

A general framework with which to model exports consists of an equation where exports are a function of a real foreign demand indicator, relative prices and control variables:[2]

$$ln\,Export_t = \beta_P * \ln\ RelativePrices_t + \beta_D * \ln\ ForeignDemand_t + \beta_c * ControlVariables + \epsilon_t. \quad (1)$$

The coefficient β_P is interpreted as the elasticity of substitution between foreign-produced products and domestic tradable products, and β_D as the elasticity of exports to real foreign demand. In a setup with only two countries (i.e., one trading partner), the relative prices variable can be measured by a relative export deflator, expressed in foreign currency using the bilateral exchange rate. In the case of multiple trading partners, a trade-weighted measure of relative price deflators is typically used. Similarly, a trade-weighted average of trading partners' GDPs can represent real foreign demand. Other variables can also be included to control for factors not captured by the foreign demand indicator and relative prices, such as a variable to account for the increase in the number of a country's international trade agreements. In the end, a model based on this framework can be estimated using time-series data, to yield parameters ($\beta_P, \beta_D, \beta_c$) for a forecasting equation.

This general framework implicitly assumes constant price and demand elasticities over time and across trading partners. A vast literature focuses on trying to relax these assumptions to improve the theoretical foundations and forecasting accuracy of export equations. For example, Spilimbergo and Vamvakidis (2003) estimate a specification for manufacturing exports with two real effective exchange rates (to proxy for relative prices), one for countries belonging to the Organisation for Economic Co-operation and Development (OECD) and one for non-OECD countries. Their results suggest improved performance over a model that uses a single real effective exchange rate, thereby rejecting the assumption of constant elasticity of substitution between products from different trading partners. In other examples, Bussière et al. (2013) and Morel (2015) demonstrate the importance of using components of foreign demand expenditure, rather than total foreign demand expenditure, to explain trade dynamics. In doing

frameworks to estimate foreign demand, such as a dynamic factor model (for more information, see Binette, Chernis and de Munnik 2017).

[2] This equation can be derived from a constant elasticity of substitution demand system.

so, the authors relax the assumption of constant import elasticities across demand components.

At the Bank of Canada, staff have incorporated these insights from Bussière et al. (2013) into their current demand equation for Canadian NCX, called the foreign activity measure (FAM) (Morel 2012). Specifically, the Bank's current model specifies foreign demand as an index of four components: US consumption, US residential investment, US business investment and a real GDP index of other non-US trading partners. The weights on each of these components are estimated using quarterly historical data, and we restrict the sum of these weights so that they sum to one in order to be compatible with a balanced-growth-path model such as the Bank's ToTEM II (Dorich et al. 2013) or LENS (Gervais and Gosselin 2014).[3] The model specifies relative prices by the price of non-commodity exports relative to the deflators of the foreign demand indicators, expressed in foreign dollars using a real effective exchange rate. In addition, a control variable is included to proxy for the steady increase in trade openness observed from 1980 to the mid-2000s.[4]

Morel (2012) shows that this equation is cointegrated with Canadian NCX over the period from 1980 to 2009, that it captures the plunge in Canadian NCX observed during the Great Recession, and that its forecast accuracy is superior to that of the Bank's previous specification. Based on these results, the FAM has been incorporated as the foreign demand indicator in the Bank's current NCX forecasting equations since 2012.

However, the Bank of Canada's forecasts, as well as those of other forecasters, have systematically overpredicted Canadian non-commodity exports since 2012, contributing to a broad pattern of "serial disappointment" across numerous Bank of Canada economic activity indicators (Guénette et al. 2016). This suggests that foreign demand and/or relative competitiveness are not adequately captured by our current specifications.

This suggestion is bolstered by two recent analyses conducted at the Bank. First, Binette, de Munnik and Gouin-Bonenfant (2014) assessed the performance of 31 non-energy export categories. The authors provide evidence of significant market share losses that are unexplained by category-specific foreign demand measures for about half of the categories examined. More recently, Barnett and Charbonneau (2015) find that changes in product-specific market shares explain two-thirds of Canada's decline in US import market share. A key takeaway from these results is that compositional changes in foreign demand do not appear to be driving the losses in Canada's foreign market share over time. Rather, changes in the

[3] The current model is estimated using data from 1980 to 2009.
[4] This variable is calculated as the share of trade (the sum of exports and imports) in GDP in OECD countries.

relationship between foreign demand, relative prices and Canadian NCX, or omitted variables, could be at the heart of this decline.

These findings emphasize an important shortcoming in the above models of relying on reduced-form estimation for the relationships described in them. Unlike structural parameters, which capture deep time-invariant relationships, reduced-form parameters are time-dependent and prone to structural breaks. Indeed, Hooper, Johnson and Marquez (2000) suggest that the estimated values of the parameters of a standard Canadian export cointegrating relationship show some signs of instability around the introduction of the North American Free Trade Agreement (NAFTA) in the early 1990s. Our own analyses also show that parameter estimates vary significantly when we enlarge the original sample set used in Morel (2012) with the recent data (see Section 3.1).

In the next section, we discuss an alternative specification that addresses some of the concerns outlined above.

Section 3 | New Specification

Our proposed equation for Canadian NCX starts with the same empirical specification as Morel (2012), in which real NCX *(NCX)* is regressed on a measure of relative prices *(RelPrice)*, a global real demand indicator *(Demand)*, and a control variable to proxy the evolution of trade openness *(Trade):*

$$\ln NCX_t = \beta_0 + \beta_1 * \ln RelPrice_t + \beta_2 * \ln Demand_t + \beta_3 * Trade_t + \beta_4 * Comp_t + \epsilon_t. \quad (2)$$

However, our specification departs from Morel (2012) in several ways. First, we modify the global real demand indicator. Second, we include an additional control variable for Canada’s manufacturing share (*Comp*). Third, relative prices are captured by the Canadian real effective exchange rate (CEER) developed by Barnett, Charbonneau and Poulin-Bellisle (2016).

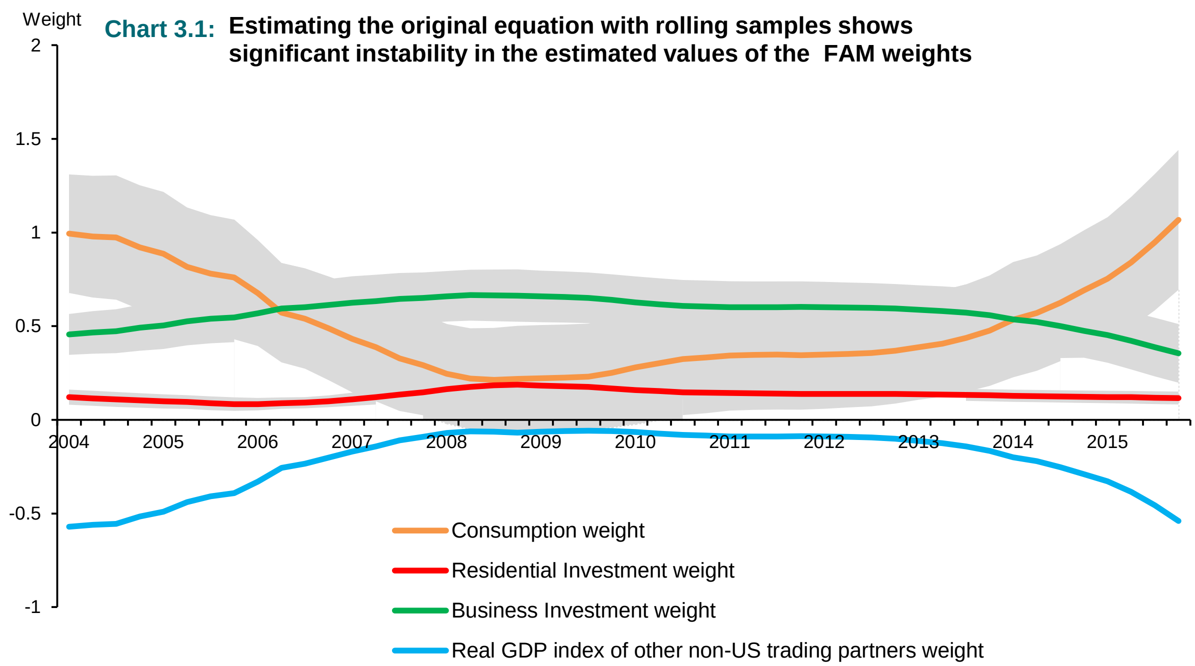
We discuss these changes in the next subsections.

Section 3.1 | Foreign demand

Real foreign demand in our equation is inspired by the foreign activity measure (FAM) developed by Morel (2012). As discussed above, the 2012 specification of the FAM includes four foreign demand indicators: US consumption, US residential investment, US business investment and a real GDP index of other non-US trading partners. In addition, we include indicators for US exports and US government expenditures to make our measure of foreign demand more comprehensive.

In Morel (2012), the relative weights assigned to the different components of the FAM are estimated, with the constraint that they sum to one. [5] When we try replicating these results, we find that the values of the estimated weights are sensitive to the sample set used for the estimation. Adding or subtracting a few years of observations leads to significantly different estimates for the weights, as illustrated by **Chart 3.1**.[6] Augmenting the specification with new control variables for structural or competitiveness factors to better isolate the effects of demand does not solve this instability issue.

Chart 3.1: **Estimating the original equation with rolling samples shows significant instability in the estimated values of the FAM weights**



Given the reduced-form nature of our specification, multiple factors could explain the instability of these estimated foreign demand weights in the estimation framework described above. For example, the weights might change over time due to structural or transitional changes in US demand or Canadian supply brought about by the Canada-United States Free Trade Agreement

[5] Because the FAM is integrated in the Bank's projection models ToTEM and LENS, it must respect certain equilibrium restrictions such that, in the long run, exports grow at the same pace as foreign demand. To respect this balanced-growth condition, the relative weights of the components of foreign demand must equal to one, and the coefficient β_2 in front of foreign demand in equation (2) must also be equal to one.

[6] Note that the parameter estimates for all estimation windows depicted in Chart 3.1 are different from the estimates found by Morel (2012). This is due to several factors, including data revisions, differences in sample periods and slight changes to the definitions of some explanatory variables.

(CUFTA) or NAFTA. This instability can be problematic in the context of a forecasting model, since it may be accompanied by systematic forecast errors.

Because the reduced-form nature of our specification does not allow us to estimate stable weights for the components of foreign demand, we decided to calibrate them as follows:

- The weighted sum of the US indicators is equal to 0.7, which is based on a rough average of the share of total Canadian NCX to the United States. The weight assigned to the real GDP index of other non-US trading partners (0.3) is also determined by the share of Canadian NCX with its other trading partners. [7]
- We calibrate the weights for the US demand subcomponents based on the 2014 World Input-Output Tables (WIOD). [8]

The WIOD provides a country-by-country breakdown of bilateral exports and imports decomposed by industry of origin and industry of destination. One of the advantages of the 2014 WIOD tables is that industries are at a suitable level of aggregation (i.e., ISIC Revision 4) to facilitate a measure of Canadian NCX that is fully consistent with the Bank of Canada's current definition of NCX.[9]

We group Canadian NCX to the United States into three US final demand categories:

- US personal consumption goods and services (*wc*=0.35)
- US gross fixed capital formation (business investment) (*wk*=0.26)
- US intermediate goods and services (*wm*=0.39)

where *wc*, *wk* and *wm* are calibrated to correspond to the shares of Canadian NCX that are directly destined for US final consumption, US gross fixed capital formation and US intermediate goods and services use, respectively, according to the 2014 WIOD.

[7] These other non-US trading partners regroup as the euro area, Japan, China, emerging-market economies (EMEs) and the "rest of world," which is a grouping of all other economies not included in the first four regions. The exact composition of the groups for EMEs and "rest of the world" is described in Table 1 on page 2 of the July 2015 *Monetary Policy Report*.

[8] For details on how the WIOD is constructed, see Timmer (2012).

[9] The Bank of Canada's definition of Canadian NCX excludes several industries that are typically associated with manufacturing, based on standard industrial classifications (e.g., ISIC Revision 4). The set of Canadian exporting industries considered in this calibration includes, in addition to service industries, the following 10 manufacturing industries: i) manufacture of food products, beverages and tobacco products; ii) manufacture of textiles, wearing apparel and leather products; iii) manufacture of printing and reproduction of recorded media; iv) manufacture of basic pharmaceutical products and pharmaceutical preparations; v) manufacture of computer, electronic and optical products; vi) manufacture of electrical equipment; vii) manufacture of machinery and equipment not elsewhere classified; viii) manufacture of motor vehicles, trailers and semi-trailers; ix) manufacture of other transport equipment; x) manufacture of furniture; other manufacturing.

Intermediate goods and services exports are then further decomposed into their use as inputs in the production of US output components, which consists of both goods and services destined for US consumption and investment and US exports. This yields the following five indicators:

- US personal consumption goods and services (*wc**=0.58)
- US gross fixed capital formation (business investment) (*wk**=0.30)
- US exports (*wx**=0.04)
- US government expenditures (*wg**=0.05)
- US residential investment (*wr**=0.02),

where *wc**, *wk**, *wx**, *wg** and *wr** are calibrated to correspond to the shares of Canadian NCX that are destined (whether directly or indirectly through intermediate inputs) for US final consumption, US gross fixed capital formation (excluding the construction sector), US exports, US government expenditures and US gross fixed capital formation in the construction sector, respectively, according to the 2014 WIOD.[10]

We also consider an alternative model, which directly factors in the importance of US industrial production (IP) as a destination of Canadian intermediate goods. In this model, Canadian NCX to the United States is broken down as the following:

- US personal consumption goods and services (*wc**=0.48)
- US gross fixed capital formation (business investment) (*wk**=0.26)
- US government expenditures (*wg**=0.05)
- US residential investment (*wr**=0.02)
- US industrial production (*wip**=0.18),

where *wc** now excludes indirect Canadian NCX content of US goods consumption, and *wk** now excludes indirect Canadian NCX content of US non-residential investment. Note that US exports are now embodied as a component of US IP and hence not directly included in the specification.[11]

[10] To measure the final-use destination of Canadian intermediate NCX, we follow the standard approach defined by Hummels, Ishii and Yi (2001). Specifically, with K industries, defining Kx1 vectors of US final consumption (*F*), non-residential investment (*K*), residential investment (*R*), exports (*X*) and government expenditures (*G*), and KxK matrices of US domestic intermediate use (*Ad*) and Canadian intermediate NCX to the US (*Ac*), the Canadian NC intermediate content of US "*Y*" is calculated as: $C\_Y = Ac((I\text{-}Ad)^{\wedge}(-1))Y$ where $(I\text{-}Ad)^{\wedge}(-1))$ represents the Leontief inverse for US domestic intermediate input use. We then calculate shares across each of *Y=F,K,R,X* and *G*, and then weight each of these by the total share of intermediates in Canadian NCX (*wm*) to arrive at the shares of Canadian NCX that are indirectly destined for each of these final demand destinations.

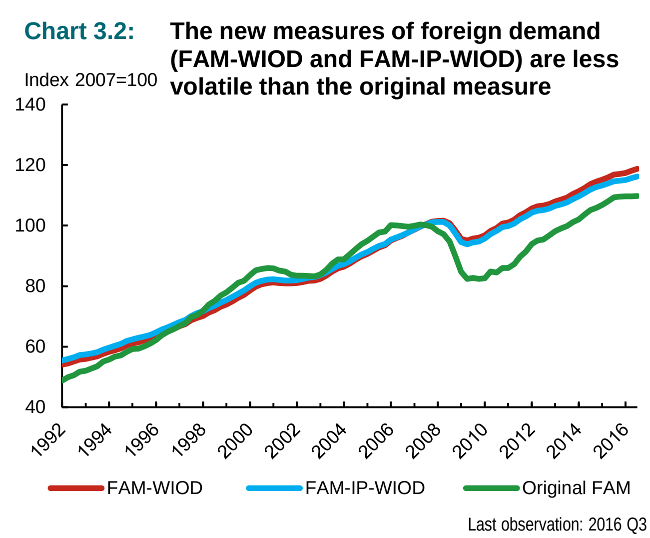
[11] These weights are also derived from the 2014 WIOD.

Table 3.1 summarizes the changes made to the foreign demand weights according to our specifications as "without IP" (denoted FAM-WIOD) and "with IP" (denoted FAM-IP-WIOD). We also include the estimated weights from the original FAM equation (denoted "original FAM") developed in Morel (2012). The weights on business and residential investment are markedly smaller in the new measures, at the expense of consumption, non-US demand and IP.

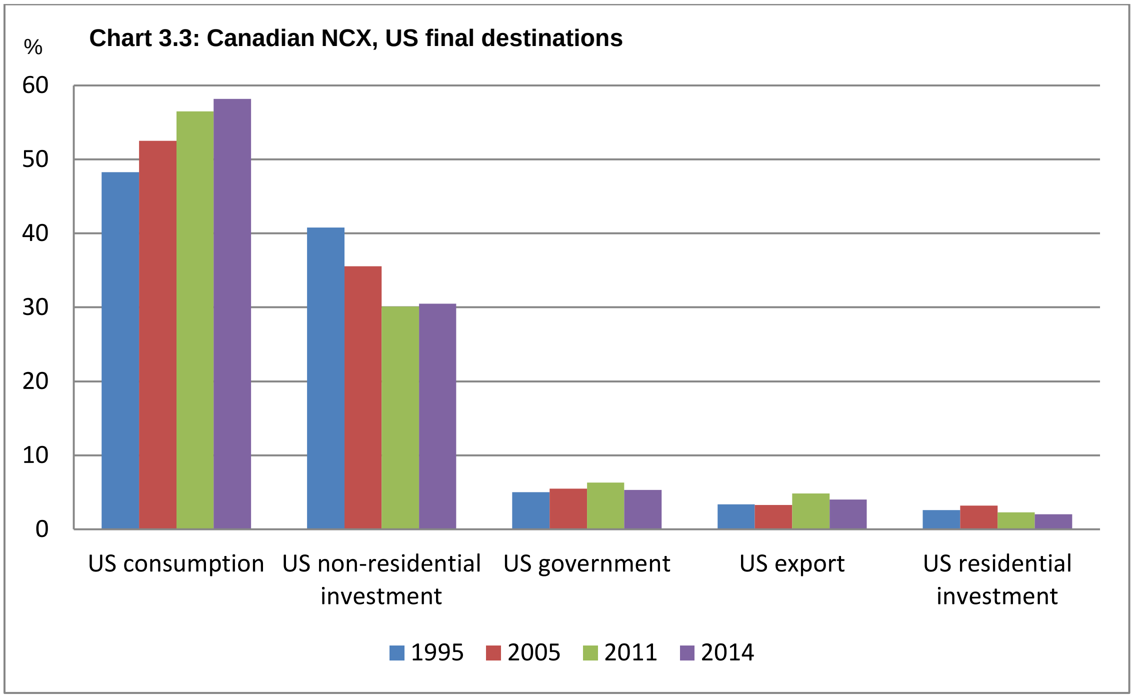
Chart 3.2 compares the evolution of the FAM-WIOD and the FAM-IP-WIOD with the original FAM. On one hand, we can see that the evolution of FAM-WIOD and FAM-IP-WIOD are very similar over history. On the other hand, both series display less-pronounced fluctuations than the original FAM, mainly because of the smaller weights on the residential and business investment, which are more volatile than the other components. Similarly, both series display a weaker average growth rate since 2012, again because of the smaller weight on residential and business investment, two components that have grown at a faster pace than the other components of final US demand in recent years.

Table 3.1 Comparison of the new weights for the demand components with the original FAM

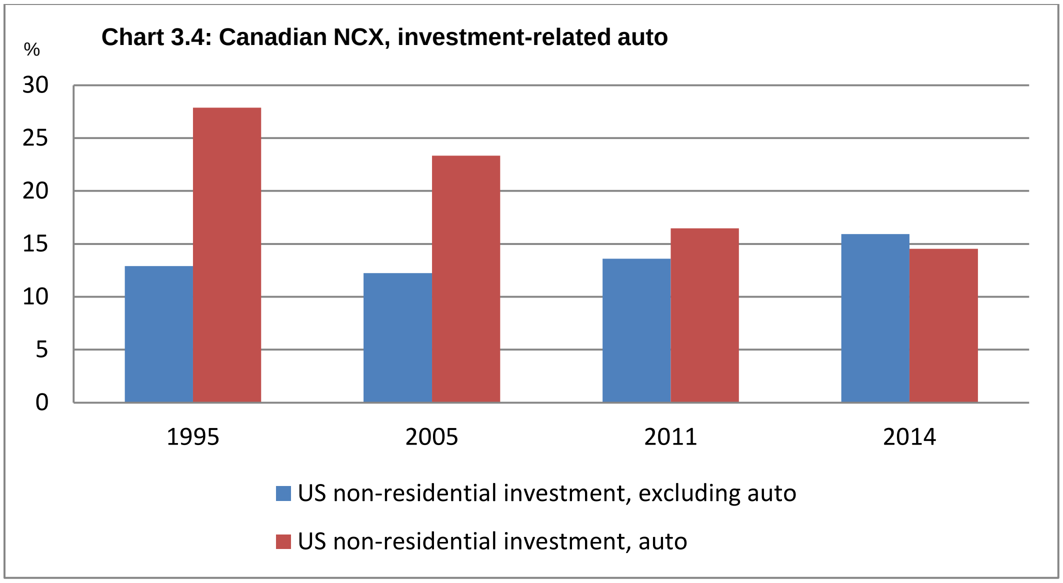
	Original FAM	FAM-WIOD	FAM-IP-WIOD
US personal consumption expenditure	0.21	0.41	0.34
US residential investment	0.18	0.02	0.02
US business investment	0.49	0.21	0.18
US government expenditures	\	0.04	0.04
US exports	\	0.03	\
US industrial production index	\	\	0.13
Real GDP index of other non-US trading partners	0.13	0.30	0.30



Given that the WIOD tables are periodically revised, there is a possibility that the weights in the new FAM measures will also be revised. **Chart 3.3** shows the evolution of Canadian NCX by US use destination from 1995 to 2014. The share of Canadian NCX destined for US consumption has steadily risen over time, from roughly 48 per cent to 58 per cent. In contrast, the share of Canadian NCX destined for US non-residential investment over this same period has declined by roughly 10 percentage points, from over 40 per cent to slightly over 30 per cent.



It is also important to note that much of this change in the weight for non-residential investment can be explained by the declining share of transport-related goods in Canadian NCX. **Chart 3.4** compares auto and non-auto investment-related goods in Canadian NCX. The share of non-auto-related investment is fairly stable, and in fact rises over the 1995 to 2014 period. In contrast, the auto-related investment share in Canadian NCX has declined significantly over this period, from nearly 28 per cent to less than 15 per cent.



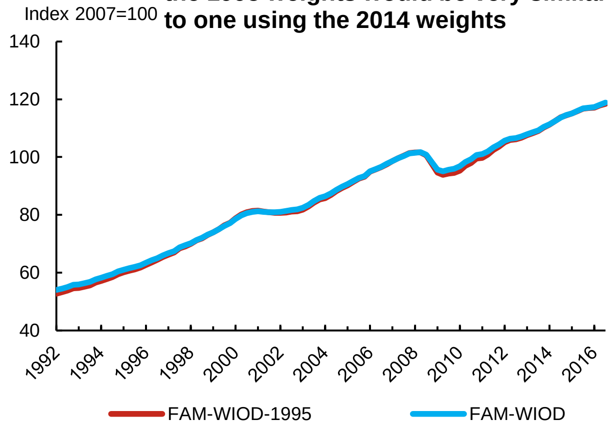
The implications of these revisions over time are relatively small for the FAM estimation. **Chart 3.5** compares a version of the FAM-WIOD where the weights are based on the 1995 WIOD tables against the FAM-WIOD displayed in **Chart 3.2**. The differences between the two series are relatively small. Moreover, the estimation results presented in Section 4 are not very sensitive to the year in the WIOD tables used to construct the new FAM-WIOD or the new FAM-IP-WIOD.

It should be noted that this calibrated approach, while addressing instability issues, remains a reduced-form relationship, and is therefore still susceptible to unpredicted structural changes.[12] That said, the calibrated FAM weights can be updated when new input-output tables are published.[13]

[12] In fact, the relative destination shares of Canadian NCX do change over time, as documented in Chart 3.3 and Chart 3.4. Fortunately, the time series provided by the WIOD covered the years 1995–2014; thus, any changes in these shares over this period can be clearly documented.

[13] Another potential caveat against using these calibrated weights is that they are derived from I-O tables, which are calculated using numerous structural proportionality assumptions. If these assumptions are incorrect, then the correct composition of Canadian exports could be different than the composition implied by the WIOD. In the end, there are no existing data (to our knowledge) on the direct linkages between Canadian NCX and foreign sectoral demand, so assumptions must be made to derive these linkages.

Chart 3.5: A measure of foreign demand based on the 1995 weights would be very similar to one using the 2014 weights



Last observation: 2016 Q3

Section 3.2 | New control variables

Our specification includes two control variables. The first is a measure of global trade intensity as in Morel (2012) to capture the secular rise in global trade elasticity observed in the period from 1985 to 2005 and the slowdown in global trade growth since the 2008 financial crisis (see **Chart 3.6** and Constantinescu, Mattoo and Ruta 2015; Francis and Morel 2015).[14]

The second is the trend component (HP-filtered) of the share of manufacturing output in Canada. As depicted in **Chart 3.7**, Canada's manufacturing share has been on a secular decline since the late 1990s. This pattern likely reflects a combination of several factors, including Canada's structural shift toward non-manufacturing production (e.g., the oil and service sectors) and the rise of Canada's manufacturing export competitors (e.g., Mexico and China).

In the end, the decline of Canada's manufacturing sector suggests that Canada's NCX capacity is much lower in recent years than it was in the past, and therefore the level of Canadian NCX should be expected to be considerably lower for equivalent values of relative prices than it was in previous periods.[15]

[14] The measure of global trade intensity is constructed as world trade over world GDP, based on IMF market exchange rate data. The series is HP-filtered and indexed to one in 1990.

[15] Although Canadian non-manufacturing NC goods are also tradable (e.g., tradable services), their trade propensity is considerably lower than that of manufacturing, so potential NCX capacity has likely fallen with the decline of Canada's manufacturing share.

Obviously, it is not surprising that this variable significantly improves the fit of our model, since an important portion of NCX is composed of manufacturing goods. Its inclusion is nevertheless essential to have a stable cointegrating relationship over time.

Chart 3.6: The increase in trade openness observed in the 1990s and early 2000s has lost its momentum since the 2008 financial crisis

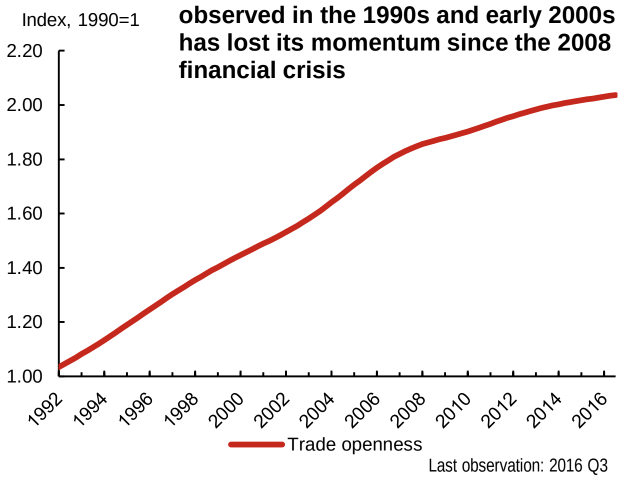
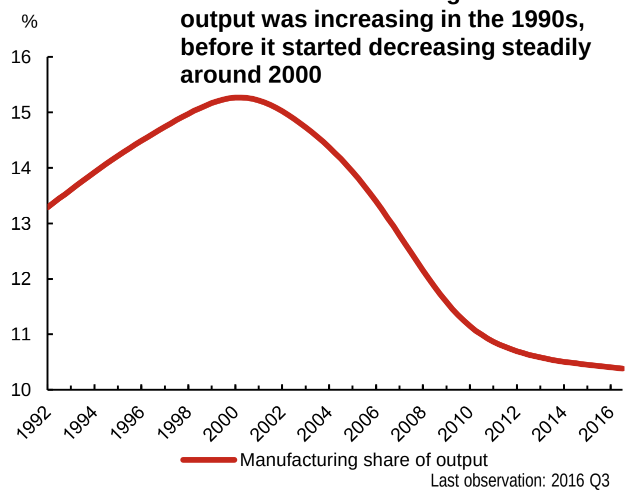


Chart 3.7: Canada's manufacturing share of output was increasing in the 1990s, before it started decreasing steadily around 2000



These two variables will be used to forecast NCX, and the Bank will therefore need to start forecasting them. Because both trends seem to have stabilized over recent years, staff at the Bank will assume a relatively flat profile for both series going forward. Obviously, there is great uncertainty around the outlook for these two series, and alternative scenarios regarding the evolution of these variables will need to be conducted frequently.

Section 3.3 | New measure of competitiveness: the updated CEER

Finally, to capture changes in relative prices, our specification includes a measure of the Canadian real effective exchange rate (CEER) developed by Barnett, Charbonneau and Poulin-Bellisle (2016). As discussed in their paper, the CEER is better suited than previous measures of the Canadian effective exchange rate to address current relative price competitiveness vis-à-vis Canada's trading partners, for three main reasons:

- The new index includes a broader set of countries.
- It uses annually updated competition-based weights.
- These weights account for both Canada's bilateral trade with another country and the competition Canada faces from that country on a product-by-product basis in third markets.

The CEER measure suggests a weaker depreciation of the Canadian dollar in recent years relative to the Bank's previous exchange rate measures.

We also tried numerous alternative proxies to capture Canada's relative prices, and none of them performed better than the CEER.

- We tried other measures of real effective exchange rates, such as the Canadian exchange rate index (CERI), but the CEER outperformed them.
- We also tried incorporating the relative prices of exports, but the addition of this variable caused a deterioration of the cointegrating relationship with NCX.
- In the same spirit as Spilimbergo and Vamvakidis (2003), we also tested specifications with multiple exchange rate measures and multiple relative import price measures of other US trading partners, but none of these improved our results.

Section 4 | Results

We estimated equation (2) described at the beginning of Section 3 with dynamic OLS using quarterly data from 1992Q1 to 2016Q3. The equation is estimated twice, once with FAM-WIOD (New equation) and once with FAM-IP-WIOD (New eq.-IP). The results are shown in **Table 4.1**.

Table 4.1 Comparison of parameters estimates

	New equation	New eq.-IP
FAM-WIOD	1.00	\
FAM-IP-WIOD	\	1.00
Real effective exchange rate	-0.24 (0.05)	-0.25 (0.05)
Trade openness	0.68 (0.03)	0.72 (0.03)
Manufacturing share of output	1.25 (0.04)	1.19 (0.04)

*Standard errors in parentheses

In both cases, the coefficient in front of the demand variable is calibrated to equal one to ensure that the balanced-growth restriction is respected, a necessary condition in ToTEM and LENS (see footnote 5).[16]

As in Morel (2012), we find that relative prices (proxied by the real effective exchange rate) and trade openness are statistically significant factors in explaining Canadian export dynamics over

[16] This restriction is not supported by the data. When we freely estimate this coefficient, it is significantly larger than one. We still impose the coefficient of one to be consistent with the economic theory, which tells us that exports should grow at the same pace as foreign demand at steady state.

time. In addition, we find that our additional control variable, the manufacturing share in Canadian output, is statistically significant and very important economically.

These new specifications show a solid cointegrating relationship with Canadian NCX. As shown in **Chart 4.1**, they both improve upon the original equation since 2000 in terms of fit and address the persistent gap between the original equation and NCX since 2012 (**Chart 4.2**). Of note, simply substituting the original FAM with the new FAM in the original framework would not be enough to get a cointegrating relationship according to standard tests (i.e., Engle-Granger, Johansen). The addition of the control variable for Canada's manufacturing market share is imperative, suggesting that export capacity, loss of competitiveness and structural changes are important factors in explaining the growth and level of Canadian NCX over time.

Chart 4.1: The cointegrating relationships of the new equations are much more robust relative to the original NCX equation…

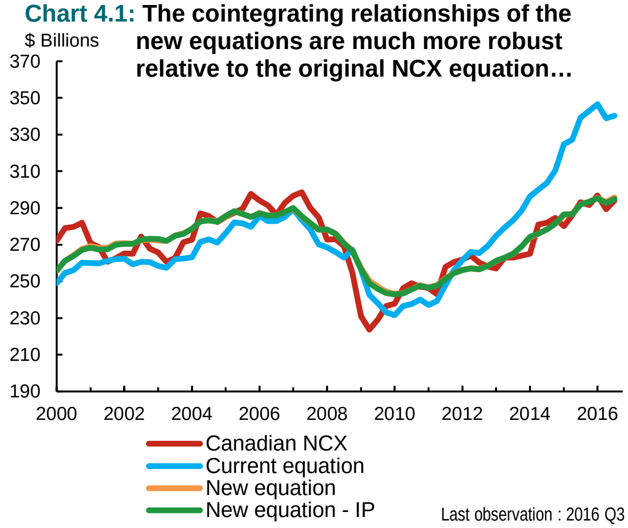
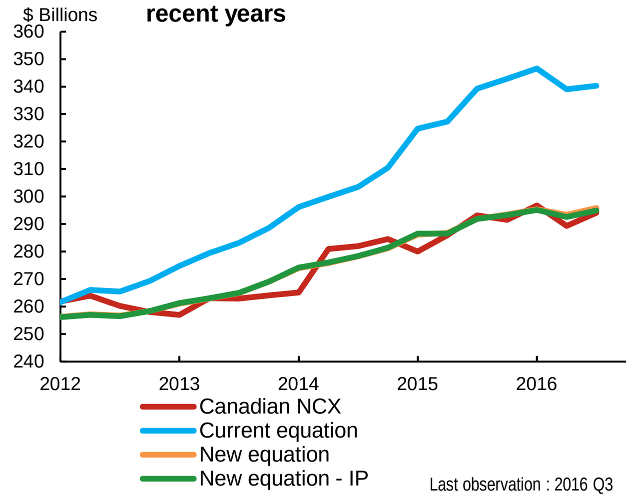


Chart 4.2: ...and they close the gap observed in recent years



Turning to our evaluation of the in-sample fit for the new equations, we consider a standard error-correction model, with the following dynamic short-run equation:

$$dlx_{ncx,t} = \beta_0 + \beta_1 * Res_{t-1} + \beta_2 * \mathrm{d}\big(dlx_{\mathrm{ncx,t-1}}\big) + \beta_2 * \mathrm{d}\big(dlx_{\mathrm{ncx,t-2}}\big) + \beta_4 * \mathrm{d}(Demand_{\mathrm{t}}) + \beta_5 \mathrm{d}(RelPrice_{t-1}) + \mu_t \text{ (3)},$$

where $dlx_{ncx,t}$ denotes the first-difference in log of NCX, Res_{t-1} the residual of the cointegrating equation (2), $\mathrm{d}(Demand_t)$ the first-difference in log of the corresponding new FAM, and $\mathrm{d}(RelPrice_{t-1})$ the first-difference in log of the relative price variable.

For comparison, we also consider a version of the Bank's current equation, which includes a forecast of Canadian NCX based on the original FAM and excludes the new control variable, Canada's manufacturing market share. This equation is similar to the specification in the Bank's model LENS. In this case, $dlx_{ncx,t}$ and $\mathrm{d}(Demand_t)$ in equation (3) are, respectively, the residual of the cointegrating equation and the first-difference in log of the original FAM.

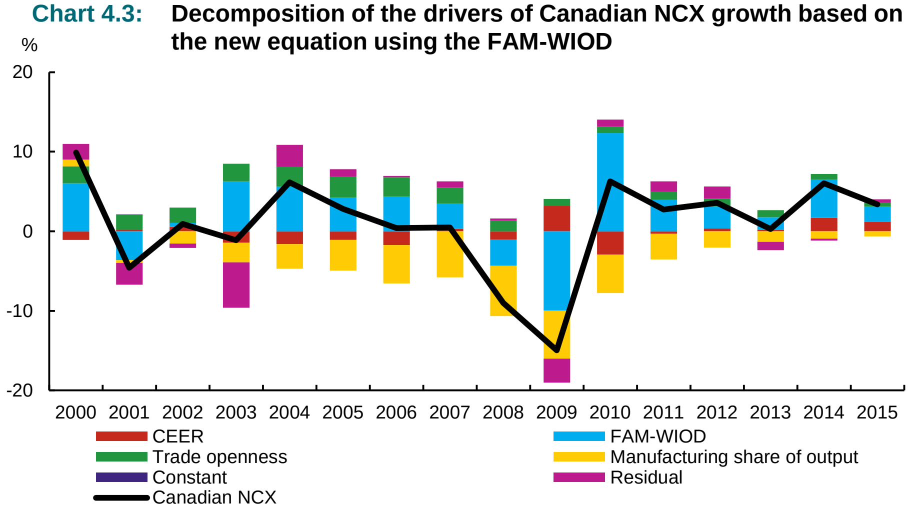
We assess the in-sample fit of our new equations, compared with the fit using the original FAM, by comparing their adjusted R-squared for equation (3) (**Table 4.2**). Additionally, we present the absolute sample mean of their residuals over three subperiods (pre-2007, 2007–2010 and post-2010) to evaluate potential bias. By and large, the in-sample fits of the new equations appear slightly superior to the original FAM. Their adjusted R-squared are slightly higher overall. In addition, a pseudo-R-squared computed with the post-2010 subset of the residuals suggests a better in-sample fit over recent years. Third, the analysis of the absolute means suggests that the new equations are less biased, especially post-2010.

Table 4.2 The new equations improve the in-sample fit, especially in recent years

	FAM-WIOD		FAM-IP-WIOD		Alternative (orig. FAM)	
	R^2	Mean	R^2	Mean	R^2	Mean
92q3-16q3	0.43	\	0.46	\	0.41	\
92q3-06q4	0.21	0.002	0.25	0.002	0.25	0.003
07q1-10q4	0.65	-0.006	0.65	-0.005	0.62	0.004
11q1-16q3	0.21	0.000	0.25	-0.001	0.10	-0.011

Chart 4.3 shows the decomposition of the drivers of NCX since 2000, based on the new equation (3) using the FAM-WIOD. Our new equation suggests that the growth of NCX was led by foreign demand and trade openness. We can also observe, however, that the downward trend of the manufacturing share of output has exerted significant drag on the growth of NCX since 2001.

Chart 4.3: Decomposition of the drivers of Canadian NCX growth based on the new equation using the FAM-WIOD



Last observation: 2015

We also evaluate the forecast accuracy of the different alternatives at one, four, and eight quarters ahead with a pseudo-real-time out-of-sample exercise. The short-run and long-run equations are estimated recursively starting in 2006Q1, carrying out NCX forecasts for the next eight quarters. Then, the sample is rolled forward one quarter and the exercise is repeated, up until 2014Q3. This exercise is performed within the ECM framework in equation (3) and assumes that the true path of the explanatory variables is known. Note that, because of this assumption, we probably underestimate the true size of the forecast errors.

Table 4.3 shows the out-of-sample root-mean-squared forecast errors (RMSFE) for the different specifications relative to the unconditional mean of NCX.[17] When the relative RMSFE is below one, the forecasts are more accurate than a naïve forecast that assumes the average growth rate of the data. From **Table 4.3**, it seems clear that the new equations improve forecast accuracy over the three different horizons, both relative to the naïve model and the original FAM-based alternative. In particular, the specification with US industrial production appears to outperform all other specifications.

Table 4.3 The forecasting accuracy of the new equations is improved, especially for the FAM-IP-WIOD specification

	Horizon (quarters ahead)		
	1	**4**	**8**
Unconditional mean	1.00	1.00	1.00
FAM-WIOD	0.76	0.61	0.53
FAM-IP-WIOD	0.70	0.47	0.44
Alternative (original FAM)	0.98	0.97	0.91

Overall, these results provide clear evidence that our new equations, which include new specifications for foreign demand and relative prices and a control variable for Canada's manufacturing share in output, outperform the Bank's previous specification.

Meanwhile, several caveats should be recognized. As mentioned previously, this exercise assumes that the true path of the independent variables is known. Naturally, this assumption artificially boosts the forecast accuracy of the forecast equations relative to the unconditional mean. More importantly, the samples of forecasts span 2008Q1–2016Q3, a period which includes the Great Recession and the "puzzle" period of slow Canadian NCX growth observed since 2012. As a result, the overall accuracy is heavily influenced by how well the forecasts from one equation match the dip in Canadian NCX observed around 2008–09 and the relatively

[17] For all horizons (h = 1, 4, and 8), we compute the RMSE over the sample of forecasts spanning 2008Q1–2016Q3.

muted growth thereafter.[18] Moreover, while our new equations provide an improved fit over the original FAM in the post-crisis period (2011Q1–2016Q3), their fit remains fairly low. While including our control variable for manufacturing share appears to explain some of the recent weakness in NCX, we do not have a conclusive understanding of the mechanism that explains this relationship, or of the remaining factors outside of our model that have likely been influential in recent years.

Section 5 | Conclusion

The current models used at the Bank to predict Canadian NCX do very well to explain the evolution of NCX before 2011. However, in recent years, these models have overestimated the growth rate of Canadian non-commodity exports (NCX). The analysis presented in this paper shows that these overestimations reflect missing variables in the specification of the NCX equations, as well as instability in the current models' estimated weights of foreign demand components.

To address these concerns, we re-estimated the NCX equation described in Morel (2012), making two important changes. First, we added a new variable to the equation, the trend of Canada's manufacturing share of output, to control for structural or competitiveness factors that affect Canada's decline in global import market share. The addition of this new variable is key to improving the fit of the NCX equation. Second, the relative price of exports is determined by a new measure of the Canadian real effective exchange rate developed by Barnett, Charbonneau and Poulin-Bellisle (2016). Third, we provide two improved measures of foreign demand by including new components (US exports, US government expenditures and US industrial production) and by calibrating the weights of its components based on the 2014 World Input-Output Tables to address issues of instability when these weights are estimated.

Overall, the new proposed equations improve the in-sample fit relative to the current NCX equation used in the Bank's LENS model and also seem to provide more solid out-of-sample forecasting performance. These updated NCX equations will be integrated in the set of tools used at the Bank of Canada to inform the staff projection on the forecasted path of NCX.

[18] Of note, if we were to exclude the Great Recession from the calculations (e.g., compute the RMSE over the sample of the forecast spanning 2009Q4–2016Q3), the new equations would have even lower relative RMSE compared with the FAM-based alternative, since they perform particularly well in the post-2009 period.

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