Explaining Slower Productivity Growth: The Role of Weak Demand Growth

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ABSTRACT

Using panel data on Canadian industries and OECD countries, this article examines empirically the role of growth in domestic and external demand in labour productivity growth. The findings suggest that most of the post-2000 slowdown in business sector labour productivity growth was the result of weak demand growth, which impacts productivity directly by reducing economies of scale and scope and by affecting key productivity drivers such as investment and R&D. With an expected slowdown in both domestic demand growth in Canada and external demand growth for Canadian exports, the medium- to long-term outlook for productivity growth, and hence for real income growth of Canadians, is expected to be weak.

CANADA'S BUSINESS SECTOR labour productivity growth increased at a meager 0.8 per cent per year since 2000, slightly over half of the pace registered during the 1981-2000 period. Productivity research has largely focused on supply-side explanations of this slowdown. In our view, the role of weaker demand conditions as a causal factor in this development has not received the attention it deserves. The objective of this article is to examine the linkages between demand and productivity growth in both Canada and OECD countries.

Labour productivity growth in Canada's manufacturing and service industries has lagged considerably behind their U.S. counterparts (Rao, 2011, and Sharpe, 2010). The dramatic slowdown in Canada's manufacturing exports and real output, largely due to the economic slowdown in the United States and Western Europe and the large real appreciation of the Canadian dollar vis-à-vis the U.S. dollar and other major currencies, seems to have contributed significantly to Canada's weak business sector labour productivity growth since 2000.

Economists and policy analysts analyze trend labour productivity growth mostly from the supply-side prism. The impact of demand on labour productivity growth is analyzed primarily in terms of their cyclical effects, via changes in the utilization rates for capital and labour.

The recent performance of Canada's manufacturing sector, the economic record of Japan, over the last two decades, and the recent economic performance of Western European coun-

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tries and emerging Asian economies strongly suggest a positive relationship between demand conditions and trend labour productivity growth. Therefore, it is important to empirically examine the linkages between demand conditions and trend labour productivity growth.

The article undertakes an empirical analysis of the potential linkages between trend productivity growth and demand conditions, drawing on the experiences at home and abroad, and examines the potential policy implications of our research findings.

This study addresses the following three key policy research questions:

- What are the key channels through which domestic and external demand conditions could influence trend labour productivity growth?
- What is the empirical evidence (both Canadian and foreign) on the impact of demand conditions on the key determinants of trend labour productivity growth? and;
- What are the potential policy implications of our new research findings?

Towards these goals, we draw on the existing research as well as undertake two types of new empirical research. First, we estimate the Verdoorn labour productivity growth equation using panel data for 35 Canadian two/three-digit NAICS industries and the aggregate data on all 34 OECD countries. Next, using the same two data sets, we regress some of the key drivers of productivity growth on two demand variables: growth in the domestic deamnd and growth in external demand.

The article is organized in five main sections. In the first section, we briefly discuss the importance of labour productivity growth for improvements in real incomes, quality of life and competitiveness in the medium- to long-term and examine the key determinants of labour productivity growth. In the second section, we discuss the channels through which domestic and external demand conditions can affect trend labour productivity growth. In the third section, we present the results from our empirical research on Verdoorn's Law. In the fourth section, we our findings on the linkages between growth in domestic and external demand and some of the key drivers of productivity growth: the investment/GDP ratio and the R&D/GDP ratio. In the last section, we summarize our key research findings and examine their policy implications as well as provide some suggestions for further research on this important topic.

Our empirical findings strongly suggest that a slowdown in domestic and external demand and economic activity sets in motion a vicious cycle of a slowdown in labour productivity, real GDP and real incomes. On the other hand, an increase in domestic and external demand and the ensuing economic activity would create a virtuous circle of an increase in the growth rate of labour productivity, real GDP and real incomes.

Labour Productivity Growth: Importance and Determinants

Productivity is the best overall indicator of a nation's underlying economic health. Over the long term, growth rates in real wages and real incomes in a country are mainly determined by trend labour productivity growth.

Labour productivity and quality of life also go hand in hand, because higher real incomes allows countries to invest more in health, education, environment and physical, telecommunication and knowledge infrastructures, and boost spending on social programs (Rao, 2011).

In the future, productivity growth will be more important to Canada ‘s economic growth than in the past decade for three key reasons.

First, because of the expected slowdown in working-age population growth and population ageing, Canada's labour force is expected to grow at a much slower pace than in the past 10 years.

Between now and 2020 the labour force is projected to increase at an average rate of 0.5 per cent per year, and could register a small negative growth thereafter. This means that the predominant source of economic growth and real income improvements in the future will be labour productivity growth.

Second, a significant part of the boost to Canada' real incomes in the post-2000 period came from terms of trade gains. This source is expected to disappear over the medium to long term, because it is highly unlikely that real commodity prices will keep on rising in the future.

Finally, to meet more effectively the growing competitive challenges from the United States and emerging economies, especially the BRIC countries, Canada needs to move up the value added chain and improve significantly its relative productivity performance, particularly in manufacturing and commercial services.

Both at the industry and aggregate levels, growth in labour productivity (real value added per hour worked) is equal to growth multifactor productivity (MFP) and the contribution from increases in capital intensity (the capital-labour ratio).

Growth in MFP captures the efficiency with which labour and capital are utilized in the production process. If capital and labour inputs are not adjusted for changes in quality over time, growth in MFP also captures changes in quality in factor inputs.[2]

Productivity research in Canada and in other countries indicates that growth in the aggregate productive efficiency, hence trend labour productivity growth, is mainly determined by scale and scope economies, improvements in human capital, innovation and innovation adoption (including international knowledge and technology transfers), as well as intra-firm and intra-industry shifts in productive inputs (for a detailed discussion, see Rao, 2011).

Impact of Demand Conditions on Key Productivity Drivers

A slowdown in domestic and external demand can create a vicious cycle of slower growth in labour productivity, real incomes and economic activity because of the negative impact of weaker demand on scale and scope economies, formation of physical and human capital, innovation and innovation adoption, entrepreneurial activity, and intra- and inter-industry shifts in productive resources.

Increasing Returns and Scale Economies

About fifty years ago, the Dutch economist P.J. Verdoorn published the results of his pioneering research on labour productivity growth and real output growth. His empirical results showed a significant positive relationship between the two variables. The real output growth coefficient for the labour productivity growth equation was around 0.5. Kaldor (1966) interpreted the strong positive relationship between the two variables as a reflection of the presence of both static and dynamic economies of scale and increasing returns. Since Kaldor's seminal work, the relationship between labour productivity growth and real output growth has been named as Verdoorn-Kaldor's Law.

Since the mid-sixties, this relationship has been examined in a large number of empirical studies, using a wide variety of data sets and employing different econometric models (e.g. Castiglione, 2011; and Libanio and Moro, 2009). Most of the empirical research to date reconfirmed the strong positive relationship between labour productivity growth and real

2 At the plant and firm levels, the appropriate concept of output for productivity analysis is gross output rather than value added, because of the importance of intermediate inputs in the production process at the micro level. In this framework, growth in labour productivity (real gross output per hour worked) will be equal to the contribution from growth in the capital-labour and the intermediate-labour ratios and growth in MFP.

output growth. Cointegration tests and Granger-causality analyses between these two variables generally confirm the presence of Verdoorn-Kaldor's Law, with causation running from change in output growh to change in productivity growth.

Human Capital

Human capital is a summary measure of educational attainment and the skills and experience of the labour force. It is a key determinant of productive efficiency and is a strong complement to the other key drivers of productivity, especially to innovation and innovation adoption.

A prolonged period of weak demand growth can negatively affect its human capital development via four important channels (Blanchard and Summers, 1989; Heckman and Masterov, 2007; Irons, 2009; and DeLong and Summers, 2012).

First, in a protracted period of slow growth in economic activity and weak job creation, the returns to human capital investments would be lower. This would impact negatively investment in higher education and skills development and upgrading. Second, increased family poverty arising from higher unemployment during a period of weaker economic growth could adversely impact childhood nutrition and cognitive development. A number of research studies have shown that early childhood education and cognitive capabilities are positively correlated with their lifetime educational and labour market performance. Hence, a prolonged period of slowdown in demand conditions could have long lasting adverse impact on human capital development and productivity. Third, increased long-term unemployment, especially among middle-aged and older workers, can make human capital obsolete and negatively affect overall productivity. Finally, an increase in unemployment from the slowdown in economic activity could raise the natural rate of unemployment via labour market "hysteresis", creating a vicious cycle of slowdown in economic activity and productivity.

Capital Accumulation

A prolonged period of weak demand conditions and economic activity can also negatively affect the accumulation of physical capital, that is investment in machinery and equipment (M&E) and structures, because of falling capacity utilization rates, and the decline in rates of return to investments. The most recent recession experience of the United States show that fixed investment as a share of potential output declined considerably in the post-2008 period compared to the pre-recession period (DeLong and Summers, 2012). Moreover, like human capital, some of the existing physical capital could also become obsolete from the prolonged slowdown in economic activity and the resulting structural adjustments.

In short, a protracted period of slowdown in demand conditions and economic activity would affect negatively capital accumulation and capital productivity, hence affecting overall productivity growth.

Innovation and Innovation Adoption

Likewise, a long-lasting demand slowdown has negative implications for innovation and innovation adoption because of the reduced returns to investments in R&D, the slow growth in foreign trade and foreign direct investment, the slowdown in new business formation and expansion, and the increased economic uncertainty and risk premiums.

Intra- and Inter-Industry Shifts in Productive Resources

The net impact of any slowdown in demand conditions on firm dynamics and aggregate labour productivity growth will depend on the magnitude of two opposing influences.

On the one hand, a slowdown in demand conditions could result in a slowdown of entrepreneurial activity, impacting negatively R&D spending and the adoption and diffusion of new knowledge and technologies.

On the other hand, during periods of weak economic activity, increased competitive pressures from home and abroad could increase the pace of creative destruction, that is the shift of productive resources from low productivity plants to high productivity plants, raising overall productivity growth.

As per inter-industry shifts in resources, during long periods of slowdown in demand conditions, capital and labour inputs are expected to shift from more productive tradable goods (in Canada's case mostly from manufacturing industries) and services to less productive non-tradable goods and services, with negative consequences for aggregate productivity growth.

In short, a prolonged slowdown in demand can negatively impact productivity performance via its adverse influence on scale and scope economies, investments in physical and human capital, innovation and innovation adoption, and intra- and inter-industry shifts in productive resources. In addition, the slowdown in economic activity and tax revenue and the increased spending on social programs can also reduce government spending on physical, knowledge and technology infrastructure.

The example of Japan illustrates dramatically the impact of slower economic growth on productivity growth (Table 1). In the 1981-90 period, before the Japanese financial crisis in 1991-92, total economy real output growth averaged 4.8 per cent per year and labour productivity growth averaged a very strong 4.1 per cent per year. In the 1991-2005 period after the crisis, real output growth fell to 1.3 per cent per year, and labour productivity growth to 0.5 per cent per year. The same trends were observed in Japan's manufacturing sector.

Table 1
Real Value Added, Labour Productivity and MFP in Japan, Before and After the 1991/92 Financial Crisis
(average annual growth rates, per cent)

Total Economy	1981-90	1991-2005
Real Value Added	4.8	1.3
Labour Productivity	4.1	1.5
MFP	1.7	0.1
Manufacturing Sector		
Real Value Added	6.7	0.9
Labour Productivity	6.2	2.0
MFP	3.9	0.5

Source: European Commission (2009).

Verdoorn's Labour Productivity Growth Equation

In the Verdoorn's labour productivity growth equation, the real output growth coefficient captures the impact of increasing returns and scale economies on the productive efficiency. We estimate two different Verdoorn productivity growth equations: one using panel data on 35 two/three–digit Canadian NAICS industries, and the other using the aggregate panel data on 34 OECD countries.[3]

Before estimating the Verdoorn productivity equation, we tested the data for non-stationarity and co-integration. Details on these tests are provided in Appendix 2.

Three different specifications of the Verdoorn's labour productivity growth are estimated. All three specifications control for industry (or country) fixed effects and time effects. To overcome issues related with the endogenous nature of real output growth and the capital intensity variables, we estimated all Verdoorn's productivity growth equations with instruments for these variables.

3 For details on data sources, see Appendix 1.

We used lagged GDP growth and capital intensity as well as the growth in domestic and external demand as instruments.

Verdoorn's Law

The dynamic panel model is similar to the VAR model; however we focus exclusively on the Verdoorn's effect, i.e. the real output growth coefficient. This means we are treating real output as an exogenous variable in our model. Panel-specific labour productivity is now modeled as:

(1) $\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta Y_{it} + \beta_{12}\Delta Y_{it-1} + \beta_{21}\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,\Delta LP_{it-1} + \mu_{it}$

for $t = 2...T$ and $i = 1...N$ where N is the number of panels, i.e. 35 for Canadian industries and 34 for OECD countries, LP is labour productivity, Y is real output, and k is capital intensity (defined as capital stock per worker). Output denotes real value-added (RVA) for Canadian industries and real GDP for OECD countries. Different model specifications are considered where the base model assumes $\beta_{12} = \beta_{22} = \beta_3 = 0$, i.e. conventional Verdoorn. We allow for panel-specific fixed effects, since each panel is likely to have a different asymptotic growth rate, and for time effects to capture possible common business cycle fluctuations and technological advancement across all panels. These fixed effects and time effects can be removed using a first-differencing dynamic panel. However, this gives rise to endogeneity, and an instrumental variable approach is required to produce consistent estimates. This point is further discussed in Appendix 3.

Verdoorn Equation: Canadian Industries

As expected, in all 35 Canadian industries, the growth rates in labour productivity and real value added are highly correlated. The industry Verdoorn equation is estimated using data on 35 Canadian two/three-digit NAICS industries over the 1970-2008 period.

The average annual growth rate in real value added over the sample period varies a great deal across Canadian industries, from -3.5 per cent per year in leather and allied product manufacturing to almost 6.0 per cent per year in computer and electronic product manufacturing, and information and cultural industries. Similarly, the average labour productivity growth rate also varies considerably across Canadian industries, from almost -1.0 per cent in mining and oil and gas extraction to a 6.0 per cent growth rate in computer and electronic product manufacturing.

Empirical results are summarized in Table 2. The estimated coefficient for real output growth is positive and highly statistically significant, and the size of the coefficient is fairly stable between 0.74 and 0.92 in the first two equations, suggesting a very strong impact of real output growth on labour productivity growth. In the third model, the long-term coefficients for output growth and capital intensity growth are positive and statistically significant, and their magnitudes are reasonable: 0.65 and 0.16, respectively.[4]

Using the estimated long-term coefficient for real output growth in the Verdoorn equation, we can calculate how much of the post-2000 slowdown in labour productivity growth in Canada was caused by the slowdown in real output growth.

Real GDP in Canada grew at an average rate of 1.9 per cent per year between 2000 and 2012, down one percentage point from the average growth of 2.9 per cent per year experienced in the 1981-2000 period. During the same period, business sector labour productivity growth also fell, from 1.5 per

4 The long-term coefficient on real output growth is computed by adding the coefficients on its two lagged variables, and dividing the resulting value by 1.0 minus the coefficient on the lagged dependent variable. The long-term coefficent on capital intensity growth is computed in an analogous way. For example, the long-term coefficient on real output growth variable is equal to 0.65=[(0.810-0.356)/(1.0-0.304)]. The long-term coefficient on capital intensity growth variable is equal to 0.16=[(0.404-0.295)/(1.0-0.304)].

Table 2

Verdoorn's Effect in Canadian Industries: Dynamic General Moments of Method (GMM)

$$\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta RVA_{it} + \beta_{12}\,\Delta RVA_{it-1} + \beta_{21}\,\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,\Delta LP_{it-1} + \varepsilon_t$$

	Model 1	Model 2	Model 3
	$\beta_{12} = \beta_{22} = \beta_3 = 0$	$\beta_{12} = \beta_{22} = 0$	full
ΔRVA_{it}	0.942***	0.923***	0.810***
	(26.998)	(27.385)	(33.986)
ΔRVA_{it-1}	..	..	-0.356***
	..	..	(-3.708)
Δk_{it}	0.512***	0.502***	0.404***
	(8.184)	(8.014)	(6.138)
Δk_{it-1}	..	..	-0.295***
	..	..	(-4.541)
ΔLP_{it-1}	..	-0.014	0.304***
	..	(-0.582)	(3.323)
H0: $\beta_{11} = 0$			
$\chi^2(1)$	728.881	749.965	
p-value	0.000	0.000	
H0: $\beta_{11} = \beta_{12} = 0$			
$\chi^2(2)$			1207.411
p-value			0.000
H0: $\beta_{11} + \beta_{12} = 0$			0.454
$\chi^2(1)$			20.058
p-value			0.000
Arellano-Bond test for AR(2) in differences (p-value)			
	0.276	0.250	0.352
No. of Obs.	1295	1260	1260
No. of Industries	35	35	35

Note: Sample is 1970-2008. Prior to reaching the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation, and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively.

cent per year in 1981-2000 to 0.8 per cent per year in 2000-2012, a drop of 0.7 percentage points.

By multiplying the drop in real GDP growth between the two periods (1.0 percentage point) by the long-term coefficient for output growth in the Verdoorn equation (0.65), dividing the resulting value (0.65) by the drop in labour productivity growth between the two periods (0.7) and then multiplying the resulting estimate by 100, we find that the contribution of the fall in real output growth to the slowdown in business sector labour productivity growth between the two periods was 93 per cent = (0.65/0.70) * 100.

As discussed in the previous section, the Verdoorn coefficient in past studies varied between 0.4 and 0.5, compared to our estimate of 0.65 for the long-term real output growth impact on trend labour productivity growth.[5]

These results imply that an increase in real output growth would create a virtuous circle, leading to more labour productivity growth and therefore more real output growth. On the other hand, a decline in real output growth, either due to a slowdown in labour force growth and/or a slowdown in domestic and external demand would create a vicious cycle of slow growth in both real output and labour productivity.

Verdoorn Equation: OECD Countries

We estimated a Verdoorn equation using aggregate panel data on 34 OECD countries over the 1970-2010 period with the same three specifications as used in the Canadian equation.

The average annual real GDP growth varied from a low of 1.6 per cent in Switzerland to a high of 7.1 per cent in South Korea. Likewise, labour productivity growth varied from a low of 1.1 per cent in Switzerland to a high of 6.0 per cent in South Korea.

The estimated coefficient for real GDP growth is once again positive and highly statistically significant in all three specifications, and the size of the coefficient is fairly stable (between 0.98 and 0.99), suggesting a strong interdependence between the two variables (Table 3). Here too the long-term coefficient on the capital intensity growth proxy variable is positive, but is small and statistically insignificant.

The size of the Verdoorn coefficient is very large, strongly suggesting that it may be capturing much of the contributions of the growth in capital intensity and technical progress to labour productivity growth.

In short, the Verdoorn productivity growth equations for both Canada and the OECD countries as a whole show a strong interdependence between labour productivity growth and real output growth, suggesting significant scale economies and increasing returns. These results imply that a slowdown in labour force growth and domestic and external demand would have a significant negative impact on labour productivity growth in the medium to long term.

Estimating the Impact of Demand on Key Drivers of Labour Productivity Growth

As discussed in the previous section, changes in domestic and external demand conditions, in addition to impacting economic activity and labour productivity growth via scale economies and increasing returns (the Verdoorn effect), can also affect trend labour productivity growth through their effects on other key productivity drivers.

Demand conditions can be described as exogenous growth in domestic and external demand. This suggests a panel model with time- and panel-specific effects can be written as:

(2) $\dot{Y}_{it} = \eta_0 + \eta_1\ Domestic\dot{D}emand_{it} + \eta_3\ External\dot{D}emand_{it} + \varepsilon_{it}$

for $t = 2...T$ and $i = 1...N$ where N is the number of panels, i.e. 15 for Canadian manufacturing industries, and 34 for OECD countries. Y denotes each of the key productivity drivers. For Canadian manufacturing industries, these key drivers are: gross fixed capital (GFC) formation, machinery and equipment (M&E) investment, information and communications technology (ICT) investment, and R&D expenditure by business enterprises. For the country-level analysis, the key drivers are GFC formation, M&E investment, and R&D. Once again we allow each panel to have a different asymptotic growth rate in the key productivity drivers. For the OECD analysis, we also include a year-specific effect to capture business cycle fluctuations.

5 To check for the robustness of the estimated coefficients, we estimated separate Verdoorn equations for only Canadian manufacturing industries. As expected, the estimated coefficients in all the three models are very similar to the ones for the full Canadian industry sample. However, the longer-term coefficients on the output growth and the capital intensity variables are slightly larger than in the full sample regressions.

Table 3

Verdoorn's Effect in OECD Countries: Dynamic General Moments of Method (GMM)

$$\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta GDP_{it} + \beta_{12}\,\Delta GDP_{it-1} + \beta_{21}\,\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,L\Delta P_{it-1} + \varepsilon_t$$

	Model 1	Model 2	Model 3
	$\beta_{12} = \beta_{22} = \beta_3 = 0$	$\beta_{12} = \beta_{22} = 0$	full
ΔGDP_{it}	0.980***	0.985***	0.991***
	(89.885)	(76.847)	(73.769)
ΔGDP_{it-1}	..	..	-0.806***
	..	..	(-5.380)
Δk_{it}	0.011***	0.011***	0.002
	(3.023)	(2.989)	(0.474)
Δk_{it-1}	..	..	-0.002*
	..	..	(-1.719)
ΔLP_{it-1}	..	0.003	0.803***
	..	(0.496)	(5.239)
H0: $\beta_{11} = 0$			
$\chi^2(1)$	8079.315	5905.470	
p-value	0.000	0.000	
H0: $\beta_{11} = \beta_{12} = 0$			
$\chi^2(2)$			7337.360
p-value			0.000
H0: $\beta_{11} + \beta_{12} = 0$			0.185
$\chi^2(1)$			1.679
p-value			0.195
Arellano-Bond test for AR(2) in differences (p-value)			
	0.705	0.667	0.750
No. of Obs.	1154	1120	1120
No. of Countries	34	34	34

Note: Sample is 1970-2010. Prior to obtaining the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation,and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively.

Separate regressions capture the impact of growth in domestic and external demand on each of the key drivers of productivity under the assumption that these key drivers are not correlated, and hence no serial correlation exists among residuals from each individual regression. This assumption is easily violated. ICT investment is part of M&E investment, which is part of GFC formation by definition; R&D expenditure may well translate investment efficiency into productivity, in which case the coefficient estimates are still unbiased yet inefficient. Structural equation modeling (SEM) relaxes such extreme assumptions and allows for non-zero covariances using quasi-maximum likelihood estimators that relax the normality assumptions when estimating standard errors. In the case of SEM, our left-hand-side variable becomes a vector of the key productivity drivers, i.e. Y = (GFC M&E ICT R&D)' for regressions on Canadian manufacturing and Y = (GFC M&E R&D)' for OECD analysis.

Domestic demand measures include real consumer expenditure, real investment in residential construction and real government spending (including government investment). External demand is proxied by real exports of goods and services.

External demand also impacts domestic spending. Therefore, some of the impact of external demand on the key drivers of productivity growth would be captured by the domestic demand variable. However, it is important to introduce separately the two demand variables, because the external demand variable, in addition to capturing the usual demand-side influences, is also likely to capture the impact of increases in product specialization, competitive pressures and international knowledge and technology flows on productivity growth. Of course, it is difficult to disentangle econometrically the influence of the two demand variables.

We estimated separate equations for GFC, M&E investment, ICT investment, and R&D spending, using the panel data on Canadian manufacturing industries. We also estimated equations for GFC, M&E and R&D, using the panel data on OECD countries. All the equations for the key drivers of productivity growth are estimated individually as well as a system of equations.

All the dependent and independent variables are in growth terms. All the equations take into account industry (or country) fixed effects and time specific effects.

For both Canadian manufacturing data and OECD data, the estimated coefficients in all equations are fairly robust. However, as expected, the standard errors are generally smaller for the system equation estimates.

Canadian Manufacturing Industries

As expected, the estimated coefficients for domestic and external demand are positive in all three investment equations, except the coefficient for domestic demand for ICT in the sytem equation (Table 4). None of the coefficients for domestic demand, however, were statistically significant at the 1 per cent level.

On the other hand, the coefficients for external demand are positive, stable, and highly statistically significant in all three investment equations. These results imply that the growth in external demand is very important for the growth in all three types of investments in Canadian manufacturing industries. This finding is not surprising given that the output growth in these industries depends heavily on demand for Canadian products in foreign markets.

It is important to note that the domestic demand variable is the same across all manufacturing industries, while the external demand variable varies across these industries. This could explain the lack of statistical significance of the domestic demand variable in the investment equations.

As expected, the coefficients for domestic and external demand are positive in the two R&D equations. However, they are not statistically significant.

OECD Countries

The estimated equations for all OECD countries are given in Table 4. In the GFC equations, the estimated coefficient for domestic demand is positive and highly statistically significant in the system equation but not in the individual equation. The coefficient for external demand is only marginally significant in the system equation and is not significant at all in the individul equation. As expected, the coefficient for domestic demand is much larger than the coefficient for external demand.

Table 4
Modeling the Impact of Demand on Key Productivity Drivers: Individual Panel Regression vs. Structural Equation Modeling (SEM)

$$\Delta Y_{it} = \beta_0 + \beta_1\ \Delta DomesticDemand_{it} + \beta_2\ \Delta ExternalDemand_{it} + \varepsilon_t$$

A) Canadian Manufacturing Industries (sample 1981-2011)

Dependent Variable, ΔY	GFC		M&E		ICT		R&D	
	Individual	SEM	Individual	SEM	Individual	SEM	Individual	SEM
$\Delta DomesticDemand_{it}$	2.694*	1.653	2.659**	1.772	1.299	-0.464	1.918	2.046
	(1.931)	(1.189)	(2.083)	(1.291)	(1.266)	(-0.359)	(1.564)	(1.393)
$\Delta ExternalDemand_{it}$	1.128***	1.457***	1.077***	1.469***	0.812*	1.056***	0.300	0.281
	(3.486)	(5.059)	(2.834)	(4.635)	(2.037)	(4.512)	(0.725)	(1.019)
Constant	-13.508**	-8.915*	-11.931**	-8.281	6.412	9.713**	-2.333	-2.708
	(-2.685)	(-1.693)	(-2.399)	(-1.582)	(1.403)	(2.117)	(-0.496)	(-0.529
No. of Obs.	450	250	450	250	450	250	250	250
No. of Industries	15	15	15	15	15	15	15	15

B) OECD Countries(sample 1970-2011)

	GFC		M&E		R&D	
Dependent Variable, ΔY	Individual	SEM	Individual	SEM	Individual	SEM
$\Delta DomesticDemand_{it}$	0.314	1.839***	2.054***	2.299***	0.564***	0.707***
	(0.370)	(11.943)	(7.301)	(6.477)	(3.736)	(2.896)
$\Delta ExternalDemand_{it}$	0.080	0.160*	0.273***	0.169*	0.125	0.169
	(0.631)	(2.465)	(2.951)	(1.941)	(0.664)	(1.090)
Constant	13.236***	-3.664**	-0.877	0.998	2.061	0.714
	(5.911)	(-2.105)	(-0.343)	(0.362)	(0.732)	(0.246)
No. of Obs.	848	419	750	419	439	419
No. of Countries	32	28	30	28	28	28

Note: All variables are annual growth rates. Prior to obtaining the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation,and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively. Each individual regression model is estimated using Driscoll and Kraay (1998) standard errors, allowing for panel-specific fixed effect. The regressions examine the impact of growth in domestic and external demand on each of the key drivers of productivity under the assumption that these key drivers are not correlated by any means and hence there is no serial correlation among residuals from each regression. The structural equation modeling (SEM) captures such correlation and allows for non-zero covariances. SEM is estimated using quasi-maximum likelihood, which relaxes the normality assumptions for estimating standard errors and includes industry-specific (or country-specific) fixed effects. Numbers in parentheses are t-statistics. *, **, and *** denote 10%, 5% and 1% significance levels, respectively. Coefficients of fixed effects are not reported for space considerations.

Estimated coefficients on the two demand variables are positive and statistically significant in the M&E investment equation. Like GFC, the coefficient for domestic demand is more than ten times larger than the coefficient for external demand. Nevertheless, the coefficient on external demand in the system equation is barely statistically significant.

The coefficient for domestic demand is positive and highly statistically significant in the

R&D equation. Although positive, the coefficient for external demand is not statistically significant. This result is similar to the finding for Canadian manufacturing industries.

In short, our empirical analysis provides strong support to the proposition that the growth in domestic and external demand impacts positively the growth in gross fixed capital formation, M&E investment and R&D spending, some of the key drivers of productivity growth. These results and the findings on the Verdoorn labour productivity growth equation strongly suggest that demand conditions and trend labour productivity growth are highly interrelated.

Conclusion

Until now, economists almost exclusively analyzed productivity growth from the supply-side prism, ignoring the potential important interplay between demand conditions and trend labour productivity growth. The main objective of the article has been to examine empirically the impact of changes in economic activity and demand conditions at home and abroad on trend labour productivity growth. Towards this goal, we first estimated Verdoorn labour productivity growth equations using panel data on Canadian industries and OECD countries. Next, using the same data sets, we estimated the impact of domestic demand and external demand on key drivers of productivity growth: gross fixed capital formation, M&E investment, ICT investment and R&D spending.

Our major finding is that 93 per cent of the fall in average labour productivity growth between 1981-2000 and 2000-2012 can be attributed to the drop in real GDP growth between the two periods. Our estimates for the Verdoorn coefficient show a strong and robust positive inter-dependence between labour productivity growth, and real output growth, suggesting the presence of significant scale economies and increasing returns.

In addition, our new empirical research shows that a slowdown in growth of domestic and external demand also impacts negatively some of the key drivers of productivity growth—such as, gross fixed capital formation, M&E investment (including ICTs) and R&D spending—thus leading to lower trend labour productivity growth.

In short, our empirical findings strongly imply that the expected slowdown in demand in Canada, the United States, Japan, Europe and East Asia would negatively affect trend labour productivity growth in Canada, suggesting that the medium- to long-term outlook for real income growth in Canada could be fairly weak, with negative consequences for economic growth, government tax revenue and budget position, and spending on social programs.

The following are five key policy implications of our research findings:

- Government's medium- and long-term economic and budget planning should take into account the reality of slow growth in Canada's trend labour productivity (perhaps less than 1.0 per cent per year).
- Given the strong interplay between domestic demand and productivity, policy makers need to ensure that government deficit and debt reduction measures are gradual in nature, so that their adverse impact on domestic demand would not be excessive.
- Canada should offset some of the slowdown in demand for our goods and services in the United States and other major OECD economies by increasing exports to large and fast growing emerging economies such as China, India, Brazil, Indonesia, and South Africa. Comprehensive trade and investment agreements with these countries would be very helpful in this regard (Rao, 2012).

- Economic stimulus measures during periods of economic slowdown should mainly focus on increasing spending on key productivity drivers, in particular investment in both physical capital (especially M&E) and human capital and R&D spending.
- Policies and programs for reducing structural rigidities, improving resource allocation and functioning of the economy, and stimulating innovation and innovation adoption would also be helpful in moderating the negative consequences of a slowdown in demand conditions on economic activity and productivity in Canada.

Future research should undertake an empirical analysis of the impact of a slowdown in domestic and external demand on other key productivity drivers: investment in human capital, creative destruction and inter-industry resource shifts. In addition, firm-based research could be undertaken to empirically examine the impact of demand conditions on labour productivity growth in Canada.

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Appendices

Appendix 1: Data Sources

For Canadian industries our dataset consists of 35 two/three-digit NAICS business sector industries for the 1970-2008 period. All data are annual. Both real value added and labour productivity (value added per hour worked) are expressed in chained 2002 Canadian dollars, and obtained from Statistics Canada CANSIM Table 383-0022. The education industry is excluded from our sample due to data unavailability.

Real value-added: Real gross domestic product (GDP) valued at basic prices.

Labour input: The number of hours worked in all jobs, calculated as the product of average annual hours worked per worker and the number of jobs.

Labour productivity: Real GDP per hour worked, constructed by dividing real value-added by labour input.

Capital intensity: The ratio of capital input to hours worked. The growth of capital intensity can hence be calculated as the difference in growth rates of capital input and labour input. Capital input is available in index format with a 2002 base year.

For demand measures related to Canadian manufacturing our dataset consists of expenditure series for the 1981-2011 period. All data are quarterly, seasonally adjusted at annual rates and in chained 2007 Canadian dollars (millions), then converted into annual data. Data on household final consumption, general governments expenditures, gross fixed capital formation in residential construction and export are obtained from Statistics Canada CANSIM Tables 380-0067, 380-0080, 380-0068 and 383-0070, respectively.

Domestic demand: Consists of final household consumption expenditure on goods and services, general government expenditure and gross fixed capital formation in residential construction.

External demand: Total export of goods and services.

For key drivers for Canadian manufacturing labour productivity our dataset consists of 15 three-digit NAICS industries in manufacturing for the 1981-2011 period, with the exception of R&D for 1994-2011.[6] All data are annual and in chained 2002 Canadian dollars (thousands for various investment and millions for R&D, respectively). Data on investment is consistent with CANSIM Table 383-0025 whereas R&D expenditures are obtained from Statistics Canada CANSIM Table 358-0024.

GFC: Capital investment flow consists of information and communication technologies (ICT) machinery and equipment, non-ICT machinery and equipment, building structures and engineering structures.

6 For comparability with R&D data, several three-digit NAICS industries are combined: food, beverage and tobacco [311-312]; textile and textile products [313-314]; apparel and leather product, furniture and miscellaneous manufacturing product [315-316, 337-339]; and paper and printing related product [322-323].

M&E: Machinery and equipment (assets) consist of ICT and non-ICT machinery and equipment.

ICT: Information and communication technologies machinery and equipment consists of computer hardware, software and telecommunication equipment.

R&D: Total business enterprise research and development (R&D) intramural expenditures for work performed within the reporting company, including work financed by others.

OECD data are available through the OECD statistics portal (OECD, 2010). Data coverage varies across countries. The first eight variables are obtained from the National Account Statistics while the last is obtained from the Structural Analysis Statistics, STAN. All data is annual and in 2005 constant U.S. dollars using constant PPPs.

GDP: Gross domestic product (expenditure approach).

Pop: Total population, national account.

LP: Labour productivity as GDP (expenditure approach) per head.

Domestic demand: Consists of final consumption expenditure by households and non-profit institutions serving households (P31S14_S15), final consumption expenditure of general government (P3S13) and gross fixed capital formation in dwellings (P51N1111).

External demand: Exports of goods and services (P6).

GFC: Gross fixed capital formation (GFC, P51) consists of other buildings and structures (P51N1112), transport equipment (P51N1113-1), other machinery and equipment (P51N1113-2), cultivated assets (P51N1114), intangible fixed assets (P51N112) net of dwellings (P51N1111).

Capital intensity: Capital intensity is a ratio of GFC to population for OECD countries.

ME: Machinery and equipment (assets) consist of transport equipment and other machinery and equipment other than that acquired by households for final consumption.

RD: Total research and development (R&D) expenditures of business enterprises.

Appendix 2: Modeling Techniques

A visual stochastic process was used to investigate the time series properties prior to modeling. The Augmented Dickey-Fuller test (Dickey and Fuller, 1979) was applied to each series (in logs) by panel (by Canadian industry or by OECD country). Under the null hypothesis of a unit root we include a constant and trend at levels and a constant only at first difference. Statistical significance of ADF test statistics indicates the existence of unit root and therefore the failure to reject the null. Each series is, however, stationary at first difference as we reject the null. It is evident that all series are integrated of order one.

For the panel unit root test there is no *a priori* assumptions of homogeneity and independence across panels; provided unbalanced panel for OECD countries we apply both Fisher's test by Maddala and Wu (1999) and the Pesaran's (2007) test. These tests confirm what has been established in the individual unit root test within each panel (industry or country).

An important concern with respect to the static Verdoorn Law is whether productivity, output and capital intensity share a common deterministic component. In particular, whether or not they are stationary at levels in some linear combination will determine whether a bivariate vector error correction model (VECM) should be adopted in the presence of cointegration, as opposed to a bivariate vector autoregression (VAR) model. For each industry/country, we follow an Engle-Granger's (1987) cointegration test procedure under the null hypothesis of no cointegration.

We also consider two assumptions under which the first-stage regression is specified; productivity, output and capital intensity share a common deterministic component on one hand, while they share a common deterministic component and trend on the other. Statistical significance of test statistics indicates the existence of unit root and hence leads to a rejection of cointegration.

For panel cointegration test, we follow an error-correction-based procedure developed by Westerlund (2007). The essence is to test for the absence of cointegration by determining whether there exists error correction for individual panel members or for the panel as a whole. Once again we consider two assumptions under the null of no cointegration. In addition, we consider the possibility of a common factor across panels. A sample p-value is bootstrapped by 200 iterations provided cross-panel dependence. The failure to reject the null by panel coincides with the result from the individual cointegration test—modeling the Verdoorn's Law by VAR is then considered.

Furthermore, the Granger causality test proposed by Toda and Yamamoto (1995) confirms the existence of linkages between productivity and output, and yet these linkages are not uniform across panels. In the Canadian business sector, for instance, two-way causality runs in 11 industries, many of which are large in terms of their shares in real value added.

Appendix 3: Technique Notes on Verdoon's Law

Assume a Cobb-Douglas production function such that:

(T1) $Y_{it} = K_{it}^{a}(Ae^{\lambda t}L_{it})^{b}$

where Y, K and L denote output, capital stock and labour input (defined as total population, not employment) respectively, for country I at time t. Technological progress advances at a rate of λ. Parameter a and b are the observed output elasticities of capital and labour respectively; the assumption of increasing returns to scales implies $(a + b > 1)$.

Taking logarithms of equation (T1) and rearranging yields:

$$\log(LP_{it}) = \frac{a}{a+b}\log A + \frac{b}{a+b}\lambda t + \frac{a+b-1}{a+b}\log Y_{it} + \frac{a}{a+b}\log(K_{it}/L_{it})$$

where LP_{it} denotes labour productivity for country i at time t. K_{it}/L_{it} denotes per-capita capital. Finally, differentiating with respect to time gives rise to:

(T2) $\dot{LP}_{it} = \frac{b}{a+b}\lambda + \frac{a+b-1}{a+b}\dot{Y}_{it} + \frac{a}{a+b}\dot{k}_{it}$

where $k_{it} = K_{it}/L_{it}$ denotes per-capita capital. The above equation says labour productivity growth can be written as a weighted average of the rate of technological progress, output growth and growth in per-capita capital. Equation (T2) is also known as the capital-augmented dynamic version of Verdoorn's law by Rowthorn (1979). It is likely that per-capita capital is endogenous and so OLS estimation is inappropriate.

Ideally, the growth of per-capita capital should be included in the Verdoorn equation estimation. However, due to the lack of investment data it is typically assumed that output and per-capita capital shares exhibit the same growth rates, i.e. $\Delta log Y_{it} = \Delta log K_{it}/L_{it}$ Equation (T2) thereby collapses to:

(T3) $\dot{LP}_{it} = \frac{b}{a+b}\lambda + \frac{2a+b-1}{a+b}\dot{Y}_{it}$

Equation (T3) is the traditional Verdoorn law first introduced by Kaldor (1966); it describes a linear relationship between labour productivity growth and output growth. The Verdoorn coefficient, $(2a + b - 1)/(a + b)$, should be less than one; in particular, it equals α under the assumption of constant returns to scale.

Let us focus on equation (T2). Rewriting it yields:

(T2a) $\dot{LP}_{it} = \beta_0 + \beta_1 \dot{Y}_{it} + \beta_2 \dot{k}_{it} + \mu_{it}$

where $\beta_0 = \frac{b}{a+b}\lambda$, $\beta_1 = \frac{a+b-1}{a+b}$, and $\beta_2 = \frac{a}{a+b}$.

We estimate equation (T2a) whose optimal lag order is chosen by means of the Akaike's information criterion (AIC) and the Schwarz's Bayesian information criterion (SBIC). As for all panels the selected optimal lag structure for the dynamic equation is (1, 1), we estimate the following two equations:

(T2b) $\dot{LP}_{it} = \beta_0 + \beta_{11}\dot{Y}_{it} + \beta_{12}\dot{Y}_{it-1} + \beta_{21}\dot{k}_{it} + \beta_{22}\dot{k}_{it-1} + \mu_{it}$

There is no reason to assume common returns to scale across all panels; each panel is likely to have its characteristics. That is,

$\beta_{i0} = \beta_0 + u_{i0}$

Accounting for panel-specific effects the reduced form of equation (T2b) can then be written down as:

(T2c) $\dot{LP}_{it} = \beta_0 + u_{i0} + \beta_{11}\dot{Y}_{it} + \beta_{12}\dot{Y}_{it-1} + \beta_{21}\dot{k}_{it} + \beta_{22}\dot{k}_{it-1} + \beta_3\dot{LP}_{it-1} + \mu_{it}$

To solve the endogeneity problem of equation (4c), we adopt instrumental variables following McCombie and de Ridder (1984) and Millemaci and Ofria (2012). We consider capital intensity as an endogenous variable and we instrument $\dot{k}_{it-1}$ with output growth at time (*t*-2) and (*t*-3), capital intensity growth at time (*t*-2) and time (*t*-3), and labour productivity growth at time (*t*-2). In addition, for the OECD analysis we include logged domestic and external demand as instruments.