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# Unbundling Canada's Weak Productivity Performance: A Review of the Issues

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# Unbundling Canada's Weak Productivity Performance: A Review of the Issues

The views and opinions expressed in the research paper are those of the author alone and do not represent, in any way, the views or opinions of the Department of Industry or of the Government of Canada.

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February 28, 2010

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## Abstract

Canada is one of the few OECD countries to trail the United States in both the level and growth rate of productivity over a long period of time (1980–2005). This paper suggests a method for breaking down this productivity gap into three components: differences in allocative efficiency, the effects of scale economies, and a residual. The residual, in turn, is a function of a variety of factors, including management practices, infrastructure, and innovative activities such as R&D. Spending on innovation has direct benefits and also creates positive externalities. Measuring the contribution of all these components of productivity growth requires both firm-level and aggregate data. The paper then reviews efforts to find how economic policies work through these various channels to affect aggregate productivity. It concludes that regulation and economic policy clearly have a statistically significant effect on productivity. But there is not yet clear evidence on the economic significance of the effects. Establishing the likely quantitative importance of plausible policy changes is the highest priority for future research.

Canada and the United States share many characteristics in common—democratic government, high income, North American geography, and a basic commitment to both free markets and social justice, to name just a few. Thus, it is surprising that the relative labor productivity performance of the two countries has diverged steadily over time. This paper sketches a path for uncovering and analyzing the causes of that gap.

Important papers by Statistics Canada (2007) and by Rao, Tang and Wang (2008) document the facts that should be the starting point for analysis. Statistics Canada (2007) shows that for about 20 years, labor productivity has grown more slowly in Canada than in the United States. Rao, Tang and Wang (2008) show that this gap is not uniform across industries. The gap in growth rates was much larger for manufacturing than for the business sector as a whole, although both gaps show an acceleration since about the year 2000—that is, Canada falling behind faster since 2000 than it was before. But interestingly, in several industries (notably Construction, Printing and publishing, Non-metallic mineral products, and Primary metal products) Canada not only had a lead in labor productivity in 1997, but extended that lead through 2001. In other industries, (for example, Food and Chemicals), Canada was trailing the United States significantly in 1997, but had essentially achieved parity or a bit better by 2001. Of course, in still other industries, Canada fell behind the United States over the 1997–2001 period, leading to its aggregate relative labor productivity decline. But it is important to note the divergent performance of these industry groups, because the proposed explanation(s) should be capable of explaining not only the aggregate gap, but the heterogeneous performances of the different industries.

This paper will take the stand that to understand the labor productivity difference between Canada and the United States, it is essential to understand the source of the different rates of TFP (MFP) growth between the two countries. There are three reasons for this approach. First, Statistics Canada (2007) documents that over 1961–2006 the difference in TFP growth between the two countries accounts for more than 100 percent of the labor productivity gap! Clearly, differential TFP performance is a major driver of the difference we seek to explain. Second, over long periods of time, capital intensity (the second component of labor productivity growth) is endogenous, and should be driven by TFP growth. Thus, according to simple economic models, in the long run TFP should be the sole driver of labor productivity growth, and high TFP, high

labor productivity and high capital intensity should all go together.<sup>1</sup> Third, as Hulten (2001) reminds us, TFP growth is the "free" part of improvement in living standards. Raising capital intensity may have long-run benefits, but it also has short-run costs: in order to invest more, people need to lower consumption in the "short run"—a length of time that in this context might be measured in decades. Thus, raising TFP growth is particularly important for improving living standards and economic wellbeing at all-time horizons.

The remainder of the paper is structured as follows. In Sections I and II, we lay out a simple framework for analyzing differences in TFP growth rates between Canada and the United States at the industry level. Applying this framework will help illuminate the reasons why Canada's TFP performance has consistently lagged that of the United States, and allow us to understand the causes of the large and growing gap in labor productivity levels between the two countries. In Section III, we discuss potential reasons for the gaps we seek to explain, drawing on the results of the framework sketched in the previous sections.

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<sup>1</sup> Indeed, this prediction is consistent with the findings of Rao, Tang and Wang (2008, p. 12) when studying labor productivity gaps industry by industry: "Across the 29 industries, there is a significant positive correlation between the labor productivity and capital intensity gaps. In other words, the industries in which Canada has a productivity advantage are also generally the industries in which we have a capital intensity advantage, and vice versa (Table 4)."

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## I. Definitions

There are  $N$  goods in the economy. Firms, indexed by  $i$ , produce goods by hiring labor,  $L_i$ , and renting capital,  $K_i$ . We assume that only one firm produces each good<sup>2</sup>. When there is no ambiguity, we omit time subscripts.

We assume that there is only one type of labor and one type of capital, and so we define aggregate inputs as simple sums of the firm-level quantities:

$$K \equiv \sum_{i=1}^N K_i,$$

$$L \equiv \sum_{i=1}^N L_i.$$

The assumption of homogeneous capital and labor is made for simplicity. With heterogeneous capital and labor, we would sum over each input separately; nothing fundamental would change.

In principle, different firms may pay different prices, even for a homogeneous input (for example, if unions raise wages at some firms but not others). For any input  $J$ , let  $P_{ji}$  be the price it pays to rent or hire the input for one period. We define the aggregate (rental) prices of capital and labor as the factor payments divided by aggregate quantities:

$$P_K \equiv \frac{\sum_{i=1}^N P_{Ki} K_i}{K}$$

$$P_L \equiv \frac{\sum_{i=1}^N P_{Li} L_i}{L}$$

We denote the growth in the Divisia definition of aggregate output (equivalently, aggregate value added) by  $dv$ . We define aggregate inputs and aggregate productivity in the ways we use them throughout the paper. We define the share of each input  $J$  in aggregate value added as  $s_J^V = P_J J / P^V V$ . Aggregate inputs,  $dx^V$ , are then a share-weighted sum of primary inputs of capital and labor:

$$dx^V = s_K^V dk + s_L^V dl. \quad (1)$$

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<sup>2</sup> This is not a restrictive assumption, since we can index goods by the firms that produce them. Consumers may regard two goods as perfect substitutes, implying that they have identical prices. More restrictive is our implicit assumption of a fixed number of firms.

The shares are the aggregate *cost* of each input divided by total nominal *revenue*; note that in contrast to Solow (1957), we do not take capital's share as a residual. Thus,  $s_K^V$  and  $s_L^V$  sum to less than one if firms make economic profits. We define aggregate productivity growth as output growth minus input growth:

$$dp = dv - dx^V. \quad (2)$$

If there are economic profits, then our measure of productivity differs from Solow's because input weights do not sum to one. If economic profits are zero, then our weights and hence our productivity measure match Solow's. Given that pure profits appear small (Basu and Fernald (1997a); Rotemberg and Woodford (1995)), in practice our measure is very close to Solow's.

## II. Productivity and Technology

This section lays out our method for finding the deep determinants of TFP growth in Canada and the United States. We begin by considering TFP growth at a firm level, and then aggregate over firms to get industry-level productivity growth.

We begin with firm-level production functions for gross output, and then derive the value-added analogues. We focus on firm-level value added because of our ultimate interest in economy-wide aggregates. Aggregate final expenditure—private and public consumption, investment, and net exports—measures what society consumes today or saves for tomorrow. The national accounts identity shows that aggregate final expenditure equals the aggregate of firm-level value added—intermediate-input use cancels out. Thus, aggregating firm-level value added leads to economically sensible aggregates.

Subsection A analyzes the determinants of firm-level value added and productivity. Subsection B uses those microfoundations to analyze industry output and productivity.

### A. The Firm Level

We assume each firm has a production function for gross output:

$$Y_i = F^i(K_i, L_i, M_i, T_i), \quad (3)$$

where  $Y_i$  is gross output,  $K_i$ ,  $L_i$ , and  $M_i$  are inputs of capital, labor, and materials, which are purchased by the firm.  $T_i$  indexes all other inputs that affect production, but are not directly compensated by the firm. This includes exogenous technology, but also other factors that are



discussed in Section III.D. The firm's production function  $F^i$  may be (locally) homogeneous of arbitrary degree  $\gamma_i$  in  $K_i$ ,  $L_i$ , and  $M_i$ .  $\gamma_i$  is not constrained to be one, so  $F^i$  may have non-constant returns to scale. Each firm may produce intermediate goods, final goods, or both.

We assume that firms are price takers in factor markets, but may have market power in output markets. For any input  $J$ , let  $F_J^i$  be the marginal product. Firm  $i$ 's first-order conditions then imply that the value of the marginal product is proportional to the shadow rental cost of that input,  $P_{ji}$ .<sup>3</sup>

$$P_i F_J^i = \mu_i P_{ji}. \quad (4)$$

Firms may charge a markup,  $\mu_i$  over marginal cost:  $\mu_i = P_i / MC_i$ , where  $MC_i$  is marginal cost.

By definition, returns to scale  $\gamma_i$  equals the sum of the output elasticities with respect to all inputs. Combining this with the first-order conditions, it is straightforward to find the relationship among  $\mu_i$ ,  $\gamma_i$ , and the ratio of economic profit to total revenue,  $s_\pi^i$ :

$$\gamma_i = \mu_i (1 - s_\pi^i). \quad (5)$$

Below, we emphasize markups rather than returns to scale, since the markup determines how the social and private valuations (i.e., the marginal product and the input price) of a factor differ. However, the equation above shows the close relationship between returns to scale and imperfect competition: firms with increasing returns must charge markups to cover their costs. If economic profits are small,  $\mu_i$  and  $\gamma_i$  must be approximately the same. If returns to scale differ across firms for technological reasons (such as differences in fixed costs), then markups are likely to differ.

Following Hall (1990), cost minimization<sup>4</sup> implies that output growth,  $dy_i$ , equals the markup multiplied by revenue-share-weighted input growth,  $dx_i$ , plus gross-output-augmenting technology change,  $\frac{F_T^i T_i}{F^i} dt_i$ . So for any input  $J$  and firm  $i$ , where  $s_{ji}$  is the input's share in nominal gross output and  $dJ$  is the input's growth rate,

<sup>3</sup> For the distinction between the price paid to a factor and its shadow rental cost, see Berndt and Fuss (1986).

<sup>4</sup> Contrary to some of the statements in the literature, the derivation does not require profit-maximization. Hence the relationship we derive below is robust to any form of price-setting behavior; for example, it allows for sticky output prices and for complex dynamic pricing strategies derived from supergames (e.g. Rotemberg and Saloner [1986]). In particular, note that markups need not depend just on the elasticity of demand.

$$dy_i = \mu_i [s_{Li} dl_i + s_{Ki} dk_i + s_{Mi} dm_i] + \frac{F^i_T T_i}{F^i} dt_i \equiv \mu_i dx_i + \frac{F^i_T T_i}{F^i} dt_i. \quad (6)$$

The revenue shares need not sum to one if there are economic profits or losses; otherwise, our revenue shares coincide with Solow's shares. Note that equation applies at an instant in time; in principle, the elasticities, and the markup  $\mu_i$ , may vary over time. Thus, the economic framework imposes no assumption of constant markups, but for econometric implementation in discrete time, we later estimate only the steady-state markup and ignore its possible time variation. This procedure is consistent with a first-order log-linearization of the production function, equation (3).

Since our ultimate interest is in value added, we now derive the value-added analogues to (6). From the production side, we use the standard Divisia definition of firm-level value-added,  $dv_i$ :

$$dv_i = \frac{dy_i - s_{Mi} dm_i}{1 - s_{Mi}} = dy_i - \left[ \frac{s_{Mi}}{1 - s_{Mi}} \right] (dm_i - dy_i). \quad (7)$$

With some algebraic manipulation, we can write  $dv_i$  as:

$$dv_i = \mu_i^V dx_i^V + (\mu_i^V - 1) \left[ \frac{s_{Mi}}{1 - s_{Mi}} \right] (dm_i - dy_i) + dt_i. \quad (8)$$

where:

$$dx_i^V = \frac{s_{Ki}}{1 - s_{Mi}} dk_i + \frac{s_{Li}}{1 - s_{Mi}} dl_i \equiv s_{Ki}^V dk_i + s_{Li}^V dl_i. \quad (9)$$

$$\mu_i^V = \mu_i \frac{1 - s_{Mi}}{1 - \mu_i s_{Mi}}, \quad (10)$$

$$dt_i = \frac{F^i_T T_i}{F^i} \frac{dt_i}{1 - \mu_i s_{Mi}}. \quad (11)$$

From equation (8), real value-added growth depends on primary input growth, changes in the materials-to-output ratio, and a residual that includes technology change. The first term shows that primary inputs are multiplied by a "value-added markup". The second term reflects the

extent to which the weight on materials-input-growth in equation does not properly measure the productive contribution of intermediate inputs. Intuitively, the standard measure of value added subtracts off intermediate input growth using revenue shares, whereas with imperfect competition the productive contribution of these inputs exceeds the revenue share by the markup. The third term is the value-added-augmenting residual.

The firm's revenue-weighted value-added productivity residual,  $dp_i$ , equals  $dv_i - dx_i^V$ . Hence,

$$dp_i = (\mu_i^V - 1)dx_i^V + (\mu_i^V - 1) \left[ \frac{s_{Mi}}{1 - s_{Mi}} \right] (dm_i - dy_i) + dt_i. \quad (12)$$

Firm-level productivity growth measured in terms of value added depends in part on markups, as emphasized by Hall. In the presence of imperfect competition, however, productivity growth also depends positively on changes in the relative intensity of intermediate-input use.

## B. Aggregating over Firms

We now aggregate over firms. In what follows, "aggregate" may be taken to refer to the industry level, or to the entire private economy. Changes in the residual, including technology shocks, clearly affect measured aggregate productivity. In addition, aggregate productivity depends on changes in aggregate primary inputs, changes in the distribution of inputs across firms (when inputs have different marginal products in different uses), and changes in the intensity of intermediate input use.

Aggregate productivity growth is the difference between the growth rates of aggregate output,  $dv$ , and aggregate inputs,  $dx^V$ . In growth rates:

$$dv \equiv \sum_{i=1}^N w_i dv_i, \quad (13)$$

where  $w_i$  is the firm's share of nominal value added,  $w_i = P_i^V V_i / P^V V$ .

With some algebraic manipulation, we can write aggregate primary-input growth  $dx^V$  in terms of the weighted average of firm-level input growth, and reallocations of capital and labor:

$$dx^V = \sum_{i=1}^N w_i dx_i^V - R_K - R_L,$$

where,

$$\begin{aligned}
 R_K &= \sum_{i=1}^N w_i s_{Ki}^V \left[ \frac{P_{Ki} - P_K}{P_{Ki}} \right] dk_i, \\
 R_L &= \sum_{i=1}^N w_i s_{Li}^V \left[ \frac{P_{Li} - P_L}{P_{Li}} \right] dl_i.
 \end{aligned}
 \tag{14}$$

Combining equations (13) and (14), above, and noting that the firm-level value-added productivity residual,  $dp_i$ , equals  $dv_i - dx_i^V$ , we can write aggregate productivity as:

$$dp = \sum_{i=1}^N w_i dp_i + R_K + R_L \tag{15}$$

As we have defined the input prices, they represent differences in *shadow values* across uses (which may or may not be reflected in factor-price differences).<sup>5</sup> Thus, aggregate productivity is the weighted average of firm-level productivity shocks, plus reallocations of capital and labor among uses with different shadow values. If resources shift towards more highly valued uses, then aggregate productivity can rise even with no change in any firm-level residual.

By substituting from equation (12) for  $dp_i$  and manipulating, we can write aggregate productivity in terms of aggregate inputs, reallocations of resources, and a residual that includes technology:

$$dp = (\bar{\mu}^V - 1)dx^V + R_\mu + R_M + \bar{\mu}^V R_K + \bar{\mu}^V R_L + dt \tag{16}$$

where,

$$\begin{aligned}
 \bar{\mu}^V &= \sum_{i=1}^N w_i \mu_i^V, \\
 R_\mu &= \sum_{i=1}^N w_i (\mu_i^V - \bar{\mu}^V) dx_i^V, \\
 R_M &= \sum_{i=1}^N w_i (\mu_i^V - 1) \left[ \frac{s_{Mi}}{1 - s_{Mi}} \right] (dm_i - dy_i), \text{ and} \\
 dt &= \sum_{i=1}^N w_i dt_i.
 \end{aligned}$$

We define the sum of the reallocation terms as  $R$ , where

$$R = R_\mu + R_M + \bar{\mu}^V R_K + \bar{\mu}^V R_L. \tag{17}$$

<sup>5</sup> Note that in practice, an important reason these terms may exist is that workers who have identical observable characteristics (that is, same age, education, etc.) are not, in fact, identical. Then the reallocation terms may reflect mismeasurement of inputs due to unobserved heterogeneity.

Equation (16) relates aggregate productivity and aggregate technology. If every firm is perfectly competitive and pays the same price for factors (perhaps because factors are completely mobile), then all terms other than  $dt$  disappear, and productivity growth equals technical change. However, with imperfect competition or frictions in product or factor markets, productivity and technology may differ.<sup>6</sup>

### III. The Sources of TFP Differences

We now discuss possible sources of TFP differences between Canada and the United States. In so doing, we use the framework that we have developed in Sections I and II. However, we also discuss issues that are outside the framework but still important to investigate.

#### A. Data

Clearly, TFP growth rates may differ across two countries if they use substantially different methods for estimating real output growth. (In principle, differences in computing real input growth rates can have the same effect, but in practice these differences are too small to explain a substantial part of the observed gap.) In particular, the U.S. BLS has sometimes been accused of "over-adjusting" for the quality improvements of new computer and electronic equipment, which would make measured U.S. output and TFP growth too high. It is likely that the careful work of Rao, Tang and Wang (2008) controlled for this source of error in comparing Canada and the United States, but since it is a logical possibility it needs to be mentioned.

Basu, Fernald, Oulton and Srinivasan (2003) were conscious of this potential for bias in doing their cross-country comparison of the United States and the United Kingdom. Their method to control for it was to use U.S. deflators for the high-tech manufacturing industries, only multiplying these by the pound/dollar exchange rate before applying them to UK data. One could do the same for Canada and the United States as a robustness check, and see whether this adjustment helps eliminate the acceleration in the labor productivity gap in the 2000s.

A different data concern, common to both Canada and the United States, is that much of the growth acceleration in the last 10 years has come in the service industries. Three large service industries make a substantial contribution to the labor productivity gap between these two countries (Rao, Tang and Wang, 2008.) They are the Trade industries (Wholesale and Retail) and FIRE. These industries, especially the financial services and insurance industries in FIRE, present formidable obstacles to attempts to measure their real output correctly. Here also, one

<sup>6</sup>Jorgenson, Gollop and Fraumeni (1987) derive an equation for the case of constant returns to scale and perfect competition, so that  $dp_i = dt_i$ . Thus, they omit the terms other than  $R_k$  and  $R_L$ . They also allow for heterogeneity in capital and labor, which we have ignored for simplicity. With heterogeneity, our results generalize easily: For example, if  $R_{kk}$  is the factor-price reallocation term for capital of type  $k$ , then  $R_k = \sum_k R_{kk}$ .

needs to compare statistical procedures in the two countries to ensure uniformity, and perhaps improve the best practice so that both countries can have better output, TFP and labor productivity measures for these key industries.<sup>7</sup>

## B. Returns to Scale

The first term on the right-hand side of equation (16) shows that the average degree of returns to scale within an industry matters for explaining industry-level TFP growth. The equation expresses the coefficient in terms of the markup, but equation (5) shows the close connection between the two concepts. If there are zero profits, as suggested by the evidence discussed in Section I, then the two are identical, and the markup parameters in equation (16) can all be interpreted as the degree of returns to scale.

If firms in Canadian industries have large fixed costs and are still operating on the downward-sloping portions of their average cost curves, while U.S. firms can spread fixed costs over many more units of output, then returns-to-scale differences can explain some of the labor productivity gap between Canada and the United States. This hypothesis can be investigated by estimating returns to scale using either industry or firm data.

## C. Allocative Efficiency Effects

The main contribution of the analysis in Section II is to demonstrate that industry TFP growth (as well as the level of TFP) depends on the degree of allocative efficiency. We have already discussed the average returns to scale (markup) term, so it is easy to use that as a springboard for discussing the term  $R_\mu$  as defined in equation (16). This term shows that, even controlling for the average returns-to-scale effect, industry TFP growth is higher if firms with above-average returns to scale (markups) have higher input growth ( $dx^V$ ) than firms with below-average returns to scale. Thus, the efficiency of allocation within an industry can make significant differences to the rate of TFP growth for the industry as a whole.

The intuition behind the other allocative efficiency terms, collectively called  $R$  in equation (17), is similar. In all cases, they have to do with the fact that marginal products for the same factor (capital, labor or intermediate inputs) may not be equalized across firms. If marginal products are not equal, industry output and TFP will depend on whether additional inputs go on average to high-marginal-product or to low-marginal-product firms. Countries that succeed in having high rates of allocative efficiency have institutions that encourage high-marginal-product firms to expand and low-marginal-product firms to contract.

<sup>7</sup> See, for example, the analysis and suggestions of Wang, Basu and Fernald (2008) regarding the measurement of banking output, which are implemented in U.S. data by Basu, Inklaar and Wang (2006) for nominal output and Inklaar and Wang (2007) for real output.

This insight is important for policy, because many policy decisions influence the rate of factor reallocation from inefficient to efficient firms. These include, but are not limited to, state-imposed costs of hiring and firing, the ease of getting permits to expand a firm or enter a market, enforcement of anti-trust policies to reduce barriers to entry, and support for laid-off workers to retrain, learn new skills and find jobs at expanding firms.

This is the most difficult and data-intensive part of the suggested research. First, to construct an index of allocative efficiency for an industry, it would be necessary to have access to firm-level data for firms in that industry. To compare Canada and the United States, it would be necessary to have firm-level data for the same industries in both countries. Second, if it were found that the United States has higher levels of allocative efficiency, it would be necessary to correlate allocative efficiency with policies. This might be done by using variation in laws/regulations across Canadian provinces and U.S. states. Finally, one would need to find or construct measures of exogenous policy change, to overcome endogeneity issues.

## **D. "The Measure of Our Ignorance"**

Most economists think automatically that TFP measures technical change, but equation (16) shows that it measures many things. One of them is surely technical change. But before we identify the residual term in (16) solely with technical change, it is important to think about what else it might represent. By definition,  $dt$  is the portion of productivity growth that is not explained by either the average markup/returns to scale effect, or by the various reallocation terms. It includes technical change, but also has other components.

### **Mismeasurement**

Mismeasurement of the quality/quantity of inputs might be one component of  $dt$ . For example, if workers have more human capital than they are measured as having, the extra boost to output from highly-skilled labor may be mistakenly attributed to technical change. Mismeasurement of intermediate input and capital quality is a particular worry when dealing with disaggregated data. For example, in the U.S. productivity growth spurt that started in the late 1990s, many of the largest contributors to the productivity acceleration were service industries (finance, retail trade and wholesale trade). These were also all industries that invested heavily in information technology (IT). IT is a form of capital that has improved tremendously in quality over time. If the price deflators for IT do not capture this improvement fully, then the contribution of capital to service output growth will be overstated and the contribution of the residual to TFP growth would be overstated.

This problem can be severe for disaggregated industries (and *a fortiori* for firms). It is less problematic as one studies productivity at higher levels of aggregation. For example, in the IT example, the output of the IT-producing sector is biased downward, as is the input of the IT-using sector. If the IT is used by other domestic industries as an intermediate input, then the bias cancels at the aggregate level within the period. However, even if IT is used as capital, the

average bias over longer periods of time will be small. Of course, in an economy that is open to trade, the bias from mismeasuring the real quantity of intermediate goods need not wash out in the aggregate.

## **Infrastructure**

The input  $T$  in a firm's production function, equation (3), is best defined as any factor that affects production but is not directly compensated by the firm. Government-provided inputs of infrastructure are a case in point. (Nowadays, one also thinks of "digital infrastructure" as a key input that might be provided by the government.) Aschauer (1989) argued that physical infrastructure built by the U.S. government has historically been highly productive, accounting for a large fraction of aggregate TFP growth. Aschauer uses a OLS regression approach to estimate the benefits of infrastructure, leading to a concern that the estimate may be biased upward. Fernald (1999) uses an innovative estimation strategy to control for the endogeneity of infrastructure, and also estimates a high average rate of return to road-building specifically. However, Fernald's results suggest that the marginal product of new spending on roads is sharply lower than the high average product of the prior spending that created the U.S. national highway system.

## **X-Efficiency/Management Practices**

The assumption that firms minimize costs underlies the derivation of both equation (6), at the firm level, and equation (16), for aggregate productivity growth. Leibenstein (1966) suggested that firms may not produce the maximum output attainable for a given set of inputs, and labeled the gap between the two "X," standing for "unknown." In a similar vein, Simon (1957) proposed that agents might "satisfice"—try to achieve a target that is "good enough," instead of actually maximizing. If the extent to which firms maximize changes over time, then the resulting gain in efficiency will show up in the residual, although it will not be due to technical change. To some extent, the distinction between the two is definitional, but from a policy perspective, the policies that lead to faster technical change (discussed below) are quite different from those that might lead firms to deploy their existing inputs more efficiently.

Recent papers have sought to give content to the "X" in various ways. One of the most promising is to consider management practices and how they differ across countries. In an important paper, Bloom and van Reenen (2007) found that the quality and professionalism of managers varies significantly across countries, in a way that is correlated with the productivity and profitability of the companies they run. It is not clear from their cross-sectional study how much of the time-series variation in productivity might be explained by such management differences, but any such changes would contribute to the  $dt$  term in (16).

## **Externalities**

In principle, both high- and low-frequency externalities can contribute to a residual term in equations like (6) and (16). High-frequency externalities are often invoked in business-cycle theory, but there are few convincing descriptions of how these externalities might operate. Over long periods of time, however, knowledge externalities—from R&D spillovers, reverse



engineering and imitation—assuredly exist, and may be important. Externalities are particularly important in a policy sense, since they create a *prima facie* case for government policies to subsidize private R&D or do public R&D.

It is worth noting, however, that while there is agreement that knowledge does spill over between firms, there is no consensus about the magnitude of these effects. Sveikauskas (2007) reviews a number of studies, and concludes that firm (as opposed to government or university) R&D has a social return that is about two to three times the private return (i.e., an externality that is up to twice as large as the direct private effect). But the underlying studies have large standard errors for the key coefficients, so this is an imprecise estimate.

## "True" Technical Change

It is of course possible that the gap in labor productivity that we seek to explain is due to differences in the rate of underlying technical change in Canada and the United States. True technical change is the "residual of the residual"—what remains when we have removed everything else that we can measure.<sup>8</sup>

If this hypothesis is correct, then the implications for policy are rather dismal. The reason is that despite decades of effort by great economists, the  $dt$  term—conceptually, though not literally, the residual that Abramovitz (1956) called a "measure of our ignorance"—is not much better understood now than it was when Abramovitz wrote. The usual way to explain the residual using deeper measures of knowledge creation is to examine the effects of investment in R&D and patenting activity by firms/industries as well as the relevant public-sector investments, bearing in mind that knowledge creation often has spillovers and is subject to long lags. However, Griliches (1994) summarizes 40 years of research on these topics by writing, "But the magnitude of the estimated effects [of R&D on productivity] was modest, not enough to account for the bulk of the observed residual or fluctuations in it."

Thus, if the labor productivity gap between Canada and the United States reflects mostly true differences in the levels of technology in the two countries, then appropriate public policy measures are hard to find. Surely, subsidies for R&D or more funding for basic research are likely to do some good. But it is difficult to find evidence that such investments can close even a substantial fraction of an industry-level TFP gap.

## IV. Policies for Prosperity—An Overview

In the previous section, we developed a framework for analyzing productivity growth, which is the ultimate determinant of welfare change. To summarize, we have seen that equations (16) and

<sup>8</sup> As a matter of principle, based on the discussion above  $dt$  should be classified as the "free" part of technical change—ideas that fall like manna from heaven, as it were. Technical change that results from purposeful R&D investment should be classified as output due to capital accumulation. However, tradition allocates the output growth resulting from investments in R&D to the residual. We continue to keep it there to maintain conformity with the existing literature, while noting the inconsistency.

(17) can be combined into a simple schematic relating productivity growth to an average markup/returns to scale, an allocative efficiency effect, and a residual:

$$dp = (\bar{\mu}^V - 1)dx^V + R + dt, \quad (18)$$

where  $dt$  is partly explained by “deeper” underlying variables:

$$dt = G(\text{infrastructure, externalities, “free” technical change, management, own R\&D}). \quad (19)$$

A large number of microeconomic studies have tried to implement a productivity decomposition along the lines of (18), and have come to mixed conclusions about the relative importance of allocative inefficiency as a driver of productivity growth. However, with rare exceptions, this literature confines itself to examining the historical decomposition, which can tell us how important allocative efficiency has been in the past. But this literature generally does not try to answer the counterfactual question that is important for policy: How much extra productivity growth could we get by promoting policies to improve allocation? What policies would attain this objective most efficiently?

Several large literatures have tried to understand how  $dt$  is determined by one or more of the variables listed in equation (19). These attempts typically come closer to addressing policy issues, since they try to uncover the structural effect of R&D capital, infrastructure, etc., on the residual. Other research agendas—for example, the investment literature—try to estimate the effects of policies such as R&D subsidies on the actual quantity of R&D. Putting the two together, one can get a sense of the extent to which policy can influence productivity growth. In principle, policies could affect aggregate productivity growth by changing any of the three main components in (18), either directly or via any of the sub-components of (19). Policy evaluation, in turn, can be done by seeing how the policy in question affects one or more of the components, or by trying to ascertain directly how the policy affects the variable of ultimate interest, aggregate productivity growth.

The issues with such regressions can also be discussed in a schematic way. Suppose we have panel data for a group of individual entities, which may be firms, industries or countries. We wish to see how an outcome variable,  $Y$ , is affected by policies,  $X$ , when another variable,  $Z$ , also affect the outcome. Assuming a linear relationship for simplicity, we have

$$Y_{it} = \alpha_i + \beta_t + \gamma X_{it} + \delta(X_{it}Z_{it}) + \zeta Z_{it} + \varepsilon_{it} \quad (20)$$

The full effect of a policy change on the outcome variable is given by the partial derivative

$$\frac{\partial Y_{it}}{\partial X_{it}} = \gamma + \delta Z_{it} \quad (21)$$

Note that the policy must vary both across units and over time in order to distinguish  $\gamma$  from the individual and time fixed effects,  $\alpha$  and  $\beta$ . But if the individual observations are at the firm or industry level, then many of the most interesting policies—such as labor market regulations—are the same across all units. Others, such as investment or R&D subsidies for particular industries, may be fixed over time. If there are interactions between the effects of policies and individual characteristics, summarized by  $Z$ , then one would be able to identify part of the policy effect, the  $\delta Z$  term in (21). But this is obviously not the full effect of the policy.

Another major concern in such regressions is that the policy may be endogenous—that is,  $X$  may be correlated with the error term  $\varepsilon$ . For example, regulation may be driven in part by economic outcomes. To some extent, this problem is ameliorated by having individual and time effects in the specification. For example, if regulation is driven by aggregate shocks, or if tariff protection is enacted to help a declining industry, then the endogenous portion of the policy will be swallowed up by the time and fixed effects. However, it is the same fixed and time effects that cause problems for identifying the full effects of policy, as given in equation (21). Once again, we see a standard tension between keeping a lot of the variation in a right-hand-side variable to aid in identification, versus excluding much of the variation in an effort to reduce bias.

The norms of the economics profession suggest a strong preference for identifying part of the policy effect without bias, rather than all of it but with less precision. Thus, most of the empirical work on policies and growth in developed countries use specifications like (21), and settle for estimating a statistically significant coefficient  $\delta$ . But these papers typically do not ask whether policies account for a large fraction of productivity growth differences across firms, industries or countries. Nor do they ask whether plausible changes in policies could have a major effect on productivity growth. Thus, the policy effects literature makes a compelling case that policies do have an effect on economic growth, and identify some of the channels through which these effects work. But much of this literature is not helpful for asking whether policies have effects that are economically rather than statistically significant.

The next several sections go into these issues in more depth, and summarize important papers.<sup>9</sup>

## V. Reallocation and Growth: Theory and Evidence

A variety of economic policies—product market regulations, labor market regulations, and trade barriers—can affect the allocative efficiency of an economy. First, they might change the allocation of resources between sectors producing different goods and between firms with different productivities within each sector. Second, they can affect the pace of entry and exit, and thus change allocation in a dynamic sense.

<sup>9</sup> Sections V-VII draw heavily on Schiantarelli (2008). I am grateful to Fabio Schiantarelli for sending me his paper and allowing me to quote from it extensively.

Blanchard and Giavazzi (2003) discuss the effect of product and labour market regulation on employment and wages in the context of a model of identical imperfectly competitive firms where both the product and labour markets are non-competitive. In this model, an increase in product market reform is modelled either as an increase in the degree of substitutability between goods or as a decrease in the entry cost.

In their model, the effect of product market reform may differ between the short run and the long run. An increase in the degree of substitutability between goods leads in the short run, for a given number of firms, to lower markups, increased employment and higher real wages. However, there is no effect in the long run, because the reduced markups induce firms to exit. Product market reforms that lead to a decrease in entry costs, on the other hand, have long-run effects as well. The entry of new firms will be associated with a lower markup and higher employment and real wages. One of the main policy implications of the paper is that only policies that affect the cost of entry have long run effects, and hence are the ones that should receive the greatest attention<sup>10</sup>.

Another class of models allows for heterogeneity between firms. Bernard, Eaton, Jenson, and Kortum (2003) and Melitz (2003) focus on external barriers affecting the product market and are based on the assumption of heterogeneity in productivity. These papers allow for entry and exit of firms and show that a lowering of trade barriers generates a reallocation of resources towards more productive firms. The exit of low productivity firms and the expansion in the domestic and foreign markets of higher productivity firms gives rise to aggregate productivity growth from policy change.<sup>11</sup>

Bergoeing, Loayza and Repetto (2004) also allow for idiosyncratic heterogeneity differences in productivity and focus on how the effect of a negative aggregate productivity shock depends upon government induced rigidities in the reallocation of resources, modelled as a subsidy to existing firms. Simulation exercises show that the existence or the introduction of such subsidies increases the length of the period in which aggregate output is below potential and generates greater cumulated output losses.

Restuccia and Rogerson (2003) and Hsieh and Klenow (2006) develop models in which government generated distortions result in heterogeneity in returns to capital and labour across firms and in misallocation of resources. This misallocation may lead to much lower levels of aggregate TFP, as shown by Hsieh and Klenow (2006) using plant-level data for India and China.

Several other micro-econometric contributions address the effect of regulatory reform and privatization on productive efficiency or productivity growth. The overall conclusion is that in many instances there have been productivity gains due to increased competition.<sup>12</sup>

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<sup>10</sup> The effect of labor market reform, captured by a decrease in workers' bargaining power in a Nash cooperative bargain, will lead to a decrease in the real wage in the short run, but to an increase in employment and an unchanged real wage in the long run in the Blanchard and Giavazzi model.

<sup>11</sup> For recent micro evidence on foreign competition and trade reform see Pavnick (2002), Harrison and Revenga (1995), Harrison (1994), Levinsohn (1993). For cross-country evidence on trade liberalization see Rodriguez and Rodrick (2001), Vamvakidis (2002), and Yanikkaya (2003).

<sup>12</sup> For good reviews, see Ahn (2002), Ahn (2001), and Faini et al. (2005).

Olley and Pakes (1996) wrote an important paper on the effect of regulatory reform on the dynamics of productivity in the US telecommunication industry. They decompose aggregate (weighted) productivity levels between un-weighted average productivity and a cross term that captures whether more efficient firms have greater market shares. They use their estimate of production function parameters that control for endogeneity and sample selection to show that improved aggregate productivity performance at the industry level is due to a reallocation of output to more productive plants and not an increase in the un-weighted average productivity.

In addition to the static productivity level decomposition due to Olley and Pakes (1996) Baily, Hulten and Campbell (1992) have proposed a method to decompose aggregate productivity growth in different components. Their contribution has been refined by Griliches and Regev (1995) and by Foster, Haltiwanger and Krizan (2001). The basic idea is to break down aggregate productivity growth in a "within" component (coming from productivity improvement in continuing firms), a "between" component (due to the reallocation of resources between continuing firms), and of the component due to entry and exit.<sup>13</sup> The refinements attempt to deal with the overestimate of the contribution of entering and exiting firms inherent in Baily et al, by introducing reference productivity values in calculating the contribution of such firms. Results on the relative importance of each component of total productivity growth decompositions differ according to which decomposition is used, to whether one focuses on multi-factor or labour productivity, whether one uses employment or product weights, whether they are beginning of period or an average between the beginning and the end of period, and according to the length of the horizon chosen for the calculation.

Many estimates of the within component of labour productivity imply that it tends to be the most important component, although its weight varies across studies. In terms of equation , these results imply that the contribution of the  $R$  term is small. Bartelsman, Haltiwanger and Scarpetta (2004) find this result (a small contribution of  $R$ ) both in developed and non-transition emerging countries. Foster, Haltiwanger, and Krizan (2001) show that the contribution of entry and exit (net entry) to aggregate productivity becomes important (and positive) only at a 5/10 year horizon, reflecting the increasing share of entering/exiting firms and learning/selection effects. Bartelsman et al (2004) also show that entry is more important (and has a positive productivity effect) in most transition countries. The entry contribution tends, instead, to be negative in most OECD countries and in the non-transition emerging economies, while the exit effect is always positive.

Evidence on the importance of reallocation of market shares from low to high productivity continuing firms is also mixed. For instance Griliches and Regev (1995), and Scarpetta, Hemmings, Tressel and Woo (2002) find that it is small, whereas Baily, Hulten and Campbell (1992), and Foster et al. (2001) find it is important. Recently Melitz and Polanec (2008) have argued that even the Griliches and Regev (1995) and Foster et al. (2001) decompositions underestimate the contribution of surviving firms and overestimate the contribution of entering

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<sup>13</sup> See Haltiwanger (2000) and Ahn (2001) for a review. In some decompositions, in addition to the "within", "between" and entry/exit components there is also a "cross" component.

firms and propose a new decomposition based on Olley and Pakes (1996) that indeed enhances the empirical importance of productivity developments for the set of continuing firms, particularly of the between component.

## **VI. Innovation and Policy: Theory and Evidence**

In this section we start from a discussion of a few theoretical contributions that help us in understanding the complex links that exist between economic policies and changes in what we term  $dt$  in equation (18). Many of these policies are in the area of product market regulation.

Policy changes can have a direct effect on the productive efficiency of existing firms. Greater competition may increase the incentives to reduce X-inefficiencies, and organize work more efficiently. The theoretical literature is immense and, while agency models of managerial behaviour can rationalize why greater competition tends to reduce slack, this conclusion is by no means unambiguous. The channels of transmissions are manifold (see Nickell, Nicolitas, and Dryden, 1997). First, in a more competitive environment it may be easier for owners to monitor managers because there are greater opportunities for comparison which can lead to better incentives. Second, it is plausible that an increase in competition will increase the probability of bankruptcy and managers will work harder to avoid this outcome. Third, in more competitive markets characterized by higher demand elasticity, a reduction in costs that allows firms to lower prices will lead to a larger increase in demand and, potentially, profits.

Changes in ownership from public to private may also have important effects on the incentives for managers and workers to reduce slack. Whether or not that happens crucially depends on the market structure after privatization. One must be careful, in general, not to equate privatization or deregulation automatically with an increase in competitive pressure, particularly in sectors where increasing returns create incentives for the emergence of natural monopolies.

There are several principal-agent models that study the effectiveness of incentives and its dependence on the number of players. Hart (1983) addresses more directly the link between competition and performance. In his model, a fraction of firms are run by managers who respond only partially to monetary incentives, in the sense that they care only whether or not their income exceeds (or not) a minimum level. The resulting optimal contract consists of paying managers this minimum provided firms' profits exceed a given floor (that can be interpreted as the bankruptcy level), and zero otherwise. In this situation, any shock that induces profit maximizing firms to reduce costs will be transmitted, via lower equilibrium prices, to non-profit-maximizing firms. Their managers will also try to reduce costs in order to avoid bankruptcy and preserve the utility derived from being in control of the firm. This will lead to an increase in the level of productivity in the economy.

Product market reforms may affect not only the level of productivity, but also its growth rate through the effect that greater competition has on the incentives to introduce new products or processes that replace the existing ones. The view by Schumpeter (1942) of growth as a process of creative destruction, in which the introduction of new processes and products is associated with the destruction of old ones, underlies many recent papers, such as the endogenous growth models of Aghion and Howitt (1992) and Grossman and Helpman (1991) and the contributions

by Caballero and Hamour (1994), (1996), (1998). Impediments introduced by product or factor market regulations to reallocation of factors of production away from low return activities to high return ones may have adverse effects on an economy's aggregate performance.<sup>14</sup> In endogenous growth models, for instance, product market regulation may be seen as increasing the cost of introducing an innovation.

However, there are contrasting forces at work. In Schumpeter's (1937) thinking, the expectations of monopoly profits provide the crucial incentive for innovative activity. A decrease in monopoly profits following regulatory reform may, therefore, decrease the pace of innovation and hence growth. In addition, the degree of market power also affects the ability to innovate since it allows the accumulation of internal financial resources that can be used to finance innovation. These internally generated funds are crucial in the presence of information asymmetries that may make it difficult or expensive to obtain external funds for innovation activities. Indeed in the early quality ladder endogenous growth models by Aghion and Howitt (1992) and Grossman and Helpman (1991) and in the product variety model by Romer (1990) a reduction in rents generated by regulatory changes would adversely affect the incentive to innovate and, hence, decrease steady state growth.<sup>15</sup> Thus, product market reform in the form of trade liberalization could have ambiguous effects on growth, since the positive scale effect is counterbalanced by the (negative) effect generated by smaller rents that accrue to innovators.

Note that whereas in the product variety models the decentralized growth rate tends to fall short of the one chosen by the social planner, in quality ladder models of creative destruction this may or may not be the case, basically because the benefits of faster technological progress must be traded off against the losses in rents by the monopoly producers that are displaced. Similar ambiguities in terms of welfare implications appear in models in which relationships are characterized by specificity that generates a hold up problem, such as Caballero and Hammour (1996, 1998). Regulations that make the reallocation of resources costly can lead to technological sclerosis, in which low-productivity units are allowed to survive too long. At the same time, they may also cause the reallocation process to be unbalanced, in the sense that the destruction rate is excessive, given the low creation rate, and generates too high unemployment of the factor that appropriates part of the rent.

In the earlier quality ladder growth models referred to above, innovations are made by outsiders and not by the incumbents. In more recent models (Aghion, Harris, Vickers (1997), Aghion, Harris, Howitt, Vickers (2001), Aghion, Bloom, Blundell, Griffith and Howitt (2002), Aghion, Burgess, Redding and Zilibotti (2003), Aghion, Blundell, Griffith, Howitt and Prantl (2003), Aghion and Griffith (2005)) incumbents are allowed to innovate. In these models, the incentive to innovate depends upon the difference between pre- and post-innovation rents. Greater competition reduces both, but the latter more than the former, fostering innovation. Basically, competition may stimulate innovation because entry and the threat of entry provide an incentive

<sup>14</sup> See also Parente and Prescott (1994) who argue that the productivity gap across countries is due to excessive regulation that discourages the adoption of new technologies and protects poorly performing firms, thereby slowing the convergence to the world technology frontier.

<sup>15</sup> In the endogenous growth models reviewed here, regulatory reform can be thought of as increasing the price elasticity of demand, or decreasing the cost of entry (increasing the probability of entry), or decreasing the cost at which a competitive fringe can produce.

to innovate in order to escape competition. This effect should be stronger in industries where competition occurs between "neck-and-neck" firms, i.e. firms with similar production costs. In other terms, competition is more likely to stimulate innovation and productivity growth in sectors or countries close to the technological frontier, while the opposite holds for sectors or countries below the frontier.<sup>16</sup>

Finally, there can also be another channel through which increased competition can have a beneficial effect on innovation and growth. When principal-agent considerations such as those in Hart (1983) are inserted in an endogenous growth model, greater competitive pressure can provide an incentive for managers to speed up the adoption of new technologies in order to avoid bankruptcy and the loss of benefits from control associated with it (see Aghion, Dewatripont and Rey (1999)).

In summary, there are many ways through which product market regulation may have an impact on overall economic performance. Regulatory reform can affect factor demand and the efficiency with which labour and capital are allocated. It also will have an impact on the extent of managerial slack and on X-inefficiency in existing firms. Moreover, it can exert an influence on the process of firm dynamics and on the introduction of new products and processes, and hence on aggregate productivity growth. However, at the theoretical level there are sufficient ambiguities or caveats concerning the direction of the effect of regulatory reform on innovation that empirical research in this area is absolutely essential to come to a convincing conclusion about the overall impact of product market regulation.

Bassanini and Ernst (2002) present direct evidence for eighteen manufacturing industries in eighteen OECD countries on the effect of product and labour market regulation on R&D intensity (relative to output). R&D is used as an input based measure of innovative activities by a firm. The advantage of this measure is the fact that it is more easily available than other measures such as patent counts. The drawback is that R&D is not the only input in the innovation process and, even if it were, R&D intensity may not capture changes in its effectiveness. Finally, not all innovative efforts are measured by formal R&D spending. The regulation variables are the OECD country level time invariant measures of domestic economic regulation (state control, legal barriers to entry, price controls) and administrative regulation (administrative barriers for new firms, permit and licensing systems), in addition to time varying indicators of tariffs and non-tariff barriers. A measure of protection of intellectual property rights is also included. Controls include industry and country dummies in addition to employment share of large firms

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<sup>16</sup> See also Vives (2006) for a discussion of the effect of competition on innovation in a variety of models of imperfect competition. The paper makes the point that the theoretical predictions depend upon the measure of competitive pressure used (degree of product substitutability, ease of entry, number of competitors, market size), upon whether one considers markets with restricted (exogenous market structure) or free (endogenous) entry, and upon whether one focuses on product or process innovation. In market with free entry, decreasing entry costs increases the number of firms (variety) but decreases R&D effort per firm finalized to cost reduction. However, typically total R&D effort increases. Increasing product substitutability tends to increase R&D effort per firm but the number of varieties may decrease. In market with restricted entry an increase in the number of firms tends to reduce R&D effort at the firm level, while increasing product substitutability tends to increase R&D effort.



and import penetration. As a result, the main effect of the time invariant indices of regulation cannot be estimated, only its differential impact across some cut in the data (high tech versus low tech industries in this case).

The results suggest that non-tariff barriers have a negative effect on R&D intensity. No effect of tariff barriers is detected, although one wonders whether the presence of the import penetration variable as a regressor or the lack of variation of this indicator across EU countries may be responsible for this result. There is no evidence of a differential effect of domestic or administrative barriers comparing low tech to high tech firms. In contrast, there is a positive differential effect for employment protection in high tech industries relative to low tech in centralized systems of industrial relations. Note however that the high tech-centralized industrial relation system interaction has a negative coefficient.

Griffith and Harrison (2004) analyze also the effect of (time varying) product market regulation on R&D through changes in the markup of price over marginal cost ( $\mu$ ). Even allowing for a quadratic term, for virtually all countries the markup has a positive and significant effect on R&D. Also, in this case, the test of over-identifying restrictions suggests that some of the indicators should be included directly in the equation. The results suggest that a lower tariff rate, fewer barriers to starting a business and lower regulatory trade barriers are associated with lower R&D in the business sector. The results obtained for the manufacturing sector are similar. However, they are very sensitive to the inclusion of Finland in the sample. When Finland is excluded, one obtains a strong inverted U shaped relationship between R&D spending and the mark-up, with a few countries such as France, Italy and the Netherlands mostly on the downward sloping section, which implies that for these countries an increase in competition would spur innovation, while the opposite is true for the rest of the countries. The sensitivity of the results to country sample selection deserves to be investigated further.<sup>17</sup>

Summing up, the cross-country studies are not supportive of a strong positive effect of lower regulation on direct input measures of firms' innovative activities. Actually, the evidence suggests that lower markups associated with product market reform lead to lower R&D for most countries. However, this evidence is sensitive in manufacturing to the particular sample of countries selected for estimation.

## VII. Effects of Policies on Productivity: Direct Evidence

One might think that if productivity is the key variable of interest, and if there are good measures of exogenous policies, then one can simply study the effect of economic policies on productivity, without trying to identify the exact channels through which these effects operate. Indeed, many papers try to do just that. However, this literature is particularly vulnerable to the econometric issues discussed in the context of equation (21). For example, using the economic freedom index

<sup>17</sup> Very recent empirical work conducted at the Institute for Fiscal Studies and still in a draft stage confirms that the inclusion or exclusion of Scandinavian countries affects deeply the shape of the relationship between the mark-up and innovation. I thank R. Griffith for useful comments and information on this point.

published by the Fraser Institute and averaging data over five year periods, Card and Freeman (2004) fail to find a significant effect of regulation on the level of output per capita (or per worker) or on its growth rate, once they control for year and country effects.<sup>18</sup>

A number of studies, many done by researchers at the OECD, examine these issues using more detailed country- or even firm-level data. Nicoletti and Scarpetta (2003) provide an in-depth empirical contribution on this issue. They focus on the effect of regulation on total factor productivity growth, using cross-country data for several industrial sectors and including the regulatory variable directly in the productivity equation. Their approach is inspired by the contribution by Griffith, Redding, and Van Reenen (2004, 2003) who use an endogenous growth model to rationalize both a direct effect of R&D on growth through its effect on innovation creation, and an indirect one through the absorption of new technology. The importance of the indirect effect depends positively upon the distance from the world frontier of each industry. Instead of R&D, the authors use an OECD measure of product market regulation and also allow for a direct and indirect effect.

The productivity measure is calculated for seventeen manufacturing and six service industries for eighteen OECD countries. Three sets of results are presented. In the first one the authors use the wide coverage, but time invariant country level measures of liberalization collected by the OECD in 1998 (which is towards the end of their sample period). The regulation variables are not significant on their own in regressions that do not (cannot) include a country effect. They are significant when interacted with the technology gap in an equation that lacks country effect. The latter could have been used instead of the insignificant time invariant indicators, in order to make a more robust statement about the significance of the differential effect of regulation, depending upon the technology gap. The time invariant character of the indicators precludes an assessment of the significance of the total effect that is robust to unobserved country heterogeneity.

The time varying measures of privatisation are introduced on their own and they tend to have a positive and significant effect on productivity growth. When a time varying economy wide measure of liberalization that summarizes information about deregulation in seven service sectors is introduced, the privatization index becomes not significant, while the time varying measure of regulation is significant and positive. The issue here is whether the regulatory reforms for the service sector can be used for the economy as a whole.

In another set of results, entry barriers and privatization are considered separately for the (aggregate) manufacturing sector and the (aggregate services sector). The time varying measure of entry liberalization in manufacturing is based only on data on trade liberalization, while the one for the service sector is the summary measure of liberalization in the seven service industries. In that case, basically no significant direct or indirect effect can be detected. Only when liberalization in manufacturing is redefined as the average of trade liberalization and entry liberalization in non-manufacturing, one observes a significant direct positive effect of deregulation on TFP growth.

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<sup>18</sup> The only significant effect is on employment growth.

Finally, in the last set of results the 1998 time invariant sector specific OECD measures of liberalization are used together with time varying measures of entry liberalization for manufacturing and service industries (the former calculated again as the average of trade liberalization and entry liberalization in non-manufacturing). The equations contain country, industry, and year dummies. The results suggest that entry liberalization in services has a positive effect on productivity growth. The only significant interaction is the one between entry liberalization in manufacturing and the technology gap. Privatization continues to have a positive direct effect on productivity growth.

## VIII. Conclusions

This paper has argued that TFP is the right measure of productivity to target for policy purposes. Since the first draft of the paper was written, Basu, Pascali, Schiantarelli and Serven (2009) have shown that aggregate TFP (as opposed to technical change narrowly defined) is the right measure of welfare for a representative consumer. Given this result, the fact that more than 100 percent of the gap between Canada and the United States in labor productivity is explained by the TFP difference between the two countries is both striking and a cause for concern.

In order to formulate policies to close this gap, it is important to understand its sources. This paper suggests a decomposition of aggregate TFP growth into components coming from aggregate distortions, resource misallocation and firm-level efficiency change. Firm-level efficiency, in turn, is a function of infrastructure, R&D, managerial efficiency, and costless technical change.

The research agenda implied by this decomposition is three-fold. First and most easily done, estimate average firm-level scale economies for important groups of Canadian industries, and compare them to similar estimates for the US. Second and harder, calculate an index of allocative efficiency for the two countries, using the data from the estimates of firm-level scale effects. If the results show that there are significant differences between the US and Canada on this front, such a finding would raise a host of follow-up research questions. Third and hardest, conduct research into the sources of firm-level efficiency differences, especially in the two countries. The research should be conducted with the aim of estimating both the statistical and the economic significance of the effect of policies on efficiency.

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