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# Knowledge-Based Labor Productivity Improvements: Canada Case Study

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***Abstract:*** This paper examines the importance of Research and Development activities as a source of growth in labor productivity in the Canadian economy within last four decades. Time series data are used to develop an econometrics model that captures the interaction between labor productivity and R&D, stock of public infrastructure and trade openness. Extensive tests of quality of data, choice of model and structural breaks are performed to enrich the value of the research. Our results suggest that the type of capital involved has a significant effect on the extent of labor productivity and growth improvement. Innovation as the major characterizer of the knowledge based economy improves the labor productivity both in short and long run. The trade openness effect has been discussed in depth consequently.

***Keywords:*** productivity, Canada, knowledge

***JEL Classification:*** J240

## Introduction

The discussion on labor productivity and its importance has been on air since the early 1980's. The effect of human capital on growth was first emphasized by Lucas (1988). He shows that human capital improves productivity and, consequently, spurs growth. Romer and Becker would later confirm the validity of his findings in 1989 and 1990.

The long discussion of labor productivity was then followed by Aschauer, DeLong, Summer, Levine, Renelt, Blomstrom, Otto, VossGreenstein, Spiller, Madden, Savage and Krugman, inter alia.

The present study examines the sources of Canadian labor productivity between 1961 and 2003. Time series data is used to develop an econometrics model that captures the interaction between labor productivity and R&D, as well as the stock of infrastructure and trade openness. These variables are selected among a list of variables supported theoretically. Our results suggest that the type of capital involved

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has a significant effect on the extent of labor productivity and growth improvement. Labor productivity is improved by innovation, which is the major characterizer of the knowledge –based economy, in both the short term and the long term. Trade openness, meanwhile, has a positive effect on labor productivity in short and long-run but not in mid-run.

The remaining of this paper is organized as follows. Section 2 provides a trend analysis of labor productivity in Canada within the period of study. Part 3 focuses on the theoretical framework as well as technical approach of the paper. Section 4 discusses the results while the last section concludes.

## Trend of Labor productivity in Canada

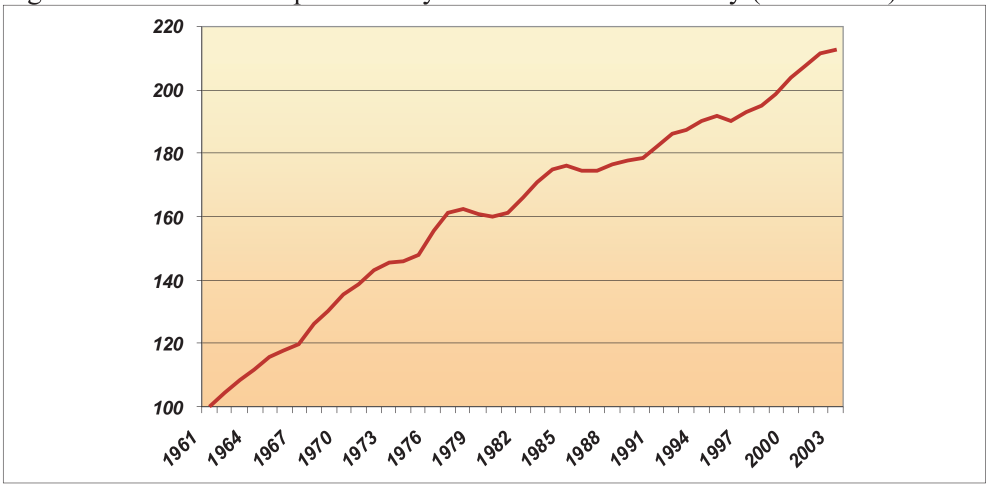
Labor productivity is the quantity of output per time spent and hours worked. It measures the efficiency of the labor input employed in the production of goods and services and the growth in it is the difference between the growth in output and the growth in labor input. Labor productivity is important because in the long-run it raises the output per worker and the growth, while improving the standard of living. The productivity improvements raise both the nominal and real income of people. The nominal income increases because, under the extreme hypothesis of pure competition, workers get the marginal value of their production. The real income increases because a higher productivity could be translated into lower production costs, lower final prices and, consequently, higher real income.

Labor productivity in the Canadian economy rose by an average of 2% annually over the course of 42 years -1961 to 2003. This could be interpreted as the output per worker doubling over a 35 year period. The 2% annual growth in labor productivity also accounts for, on average, almost 50% of growth in GDP.

Figure 1 shows the evolution of labor productivity in Canada between 1961 and 2004. The smooth increasing trend of the labor productivity has been disturbed by some spikes throughout this period. It has slightly fallen down once in 1979 and 1980 before improving again in 1981. Similar occurrences also happened in 1986 and 1996 but they were followed by immense improvements in 1987 and 1997.

There are different scenarios about the sources of Canadian labor productivity improvement. Canada's improvement in labor productivity sometimes referred to a higher capital stock in machinery and equipments, engineering constructions and building constructions. Improvements in labor skills have been seen as another source of improvement. Technological and management advances, resulting from innovation activities, have also been recognized as sources of improvement in labor productivity. The improvement in trade is responsible for a more efficient production process and therefore increases labor productivity.[1]

Figure 1: Trend of labor productivity in the Canadian economy (1961-2004)




**The Model**

Using the Aschauer (1989) supply side approach, we have broken down the evolution of labor productivity into the following[2]:

$$\frac{Y}{L} = f\left(\frac{T}{L}, \frac{IE}{L}, \frac{RD}{L}\right) \tag{1}$$

Where $Y/L$ is labor productivity, $T/L$ is public infrastructure per hours worked, $IE/L$ is economic openness per hours worked and $RD/L$ is the innovation cost per hours worked.

By infrastructure we mean the part of stock of capital in the economy which facilitates the fundamental social and economic activities in that economy. Innovation cost or R&D cost refers to expenses incurred in the process of discovering new knowledge about products and services and, in turn, applying that knowledge to create new and improved products, processes, and services that fill market needs. Economic openness takes the exports in addition to the imports and divides them by the GDP, or it is simply the proportion of GDP caused by total trade.

The variables of interests have to be tested for stationarity first. *Inter alia*, ADF, Dickey-Fuller GLS and Elliott-Rothenberg-Stock Point Optimal tests of unit root could satisfy this purpose. After dealing with non-stationarity a cointegration test would be in order. Classical methods of estimation are only recommended if the stationarity of variables are satisfied. However, existence of a unit root in any of the variables of interest necessitates a need for an alternative estimation method.

A non-stationary variable might have a long run relationship with other non-stationary variables in which case a classical method will not be sufficient in providing spurious results. This requires that non-stationary variables be tested for cointegration. *Inter alia*, Engle-Granger's residual based test (1987), Johansen's maximum likelihood based test (1988) and the Johansen-Juselius test (1990) could be used to address this concern. All of these cointegration procedures require that regressors have the same order of integration i.e. I(1) or I(2) process.

An alternative to these procedures is the Autoregressive Distributed Lag (ARDL) approach to cointegration introduced by Pesaran and Shin (1995). They show that augmented ARDL estimates are asymptotically consistent. Consequently the asymptotic theory can be used to make inference about the long-run use of ARDL results. The advantage of this approach is that it can be applied to any group of regressors regardless of their integration order[3] whether the variable is an I(0), I(1) or even fractionally integrated. Moreover, with some transformation, an Error Correction Model (ECM) can be derived from ARDL approach to cointegration. The ECM puts the short-run and long-run results together and no information will be lost during the estimation process as a result.

A cointegration test must be conducted at the start of this approach. If the null hypothesis of no cointegration is rejected at the selected critical level, the ARDL method estimates $(p+1)^k$ different regressions in order to find the optimal lag length of each variable, where $p$ and $k$ are the maximum number of lag lengths and number of the variables, respectively. The best model can be determined using information criteria such as Akaike's information criteria (AIC) and the Schwartz-Bayesian Criteria (SIC) accordingly. SIC selects the parsimonious model, which is the model with the smallest possible lag length.

Based on the selected ARDL model, the long-run relationship between the variables is estimated subsequently. If existence of cointegration between the variables is confirmed, the error correction model is estimated. The ECM representation of variables shows both the short run and the adjustment coefficient. The adjustment coefficient, or correction coefficient, refers to the speed of adjustment between status quo and the new equilibrium caused by a short-run shock.

The simplest ARDL model-a two-variable model- is as follows:

$$Y_t = \mu + \sum_{i=1}^{n} \alpha_i Y_{t-1} + \sum_{i=0}^{m} \gamma_i X_{t-1} + u_t \tag{2}$$

In order to trace a long run relationship, consider the steady-state point of the model in which $Y_t$ and $X_t$ will be equal to their steady-state levels, $Y^*$ and $X^*$ respectively. Therefore, we will have:

$$Y^{*} = Y_{t} = Y_{t-1} = Y_{t-2} = ... = Y_{t-n}$$
$$X^{*} = X_{t} = X_{t-1} = X_{t-2} = ... = X_{t-m} \tag{3}$$

So by substituting of (3) into (2), we get the long-run equation as:

$$Y^{*} = \frac{\mu}{1-\sum \alpha_{i}} + \frac{\sum \gamma_{i}}{1-\sum \alpha_{i}} X^{*} \tag{4}$$

Or simply,

$$Y^{*} = B_{0} + B_{1} X^{*}. \tag{5}$$

The conditional mean of $Y^{*}$ can be defined as,

$$Y^{*} = B_{0} + B_{1} X_{t} \tag{6}$$

And the equilibrium error as,

$$u_{t} = Y_{t} - Y^{*} = Y_{t} - B_{0} - B_{1} X_{t}. \tag{7}$$

Using OLS we can estimate $B_0$ and $B_1$ S, however the calculation of the standard errors would be very difficult. To deal with the issue in hand we can use an ECM representation of the ARDL model. Reparametrizing (2) we will have:

$$\Delta Y_{t} = \mu + \sum_{i=1}^{n-1} \alpha_{i} \Delta Y_{t-1} + \sum_{i=0}^{m-1} \gamma_{i} \Delta X_{t-1} + \theta_{1} Y_{t-1} + \theta_{2} X_{t-1} + \varepsilon_{t} \tag{8}$$

In this model $\theta_{2} = \sum_{i=1}^{m} \gamma_{i}$ (the numerator of $B_1$) and $\theta_{1} = -\left(1 - \sum_{i=1}^{n} \alpha_{1}\right)$. So the ECM will have the following form:

$$\Delta Y_{t} = \mu + \sum_{i=1}^{n-1} \alpha_{i} \Delta Y_{t-i} + \sum_{i=0}^{m-1} \gamma_{i} \Delta X_{t-i} + \theta_{1} \left( Y_{t-1} - \frac{1}{\theta_{1}} - \frac{\theta_{2}}{\theta_{1}} X_{t-1} \right) + \varepsilon_{t} \tag{9}$$

Or

$$\Delta Y_{t} = \mu + \sum_{i=1}^{n-1} \alpha_{i} \Delta Y_{t-i} + \sum_{i=0}^{m-1} \gamma_{i} \Delta X_{t-i} + (Y_{t-1} - \hat{\beta}_{0} - \hat{\beta}_{1} X_{t-1}) + \varepsilon_{t} \tag{10}$$

Here we realize that $\pi = -\theta_1$. In addition we know that $Y_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 x_{t-1} = \varepsilon_t$ therefore the above ECM could be rewritten as:

$$\Delta Y_t = \mu + \sum_{i=1}^{n-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{m-1} \gamma_i \Delta X_{t-i} + \pi \hat{e}_{t-1} + \varepsilon_t . \quad (11)$$

Here is the adjustment coefficient or error correction coefficient.

To check the extent of the fit of the ARDL model, diagnostic and stability tests could be conducted. The diagnostic tests are responsible for testing serial correlation, functional form, normality and heteroscedasticity. The cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) can be applied to check the stability of the model.

## Results

ADF, Dickey-Fuller GLS and Elliott-Rothenberg-Stock Point Optimal tests of unit root are carried on the data. All tests show that variables are non-stationary of the order of one. So we proceed with the ARDL approach to cointegration[4].

The best selected model is ARDL(1,0,0,3). This can be determined by SIC and knowing that the selected lags by AIC are higher than the optimal lags determined by SIC, i.e. SIC gives parsimonious model compare to that of AIC.

Table 1 shows the estimated long-run coefficients of the model using the ARDL approach to cointegration. All of the coefficients, except the constant, are significant at 5% level of significancy. The largest long-run effect would be experienced by the public infrastructure. This coefficient is 0.46 stating that a hypothetical increase of 1% in the stock of public infrastructure will increase the productivity of labor input by 0.46% in long-run. The coefficients of lnRDL and lnIEL are also significantly positive.

Table 2 summarizes the error correction representation of the model. All of the short-run coefficients are significant at the 10% level of significancy and except for the lagged values of lnIEL, all of coefficients are positive. This is in line with our prior expectations. The error correction term is comes out negative and significant at 1% level of significancy. The value of correction factor is -0.27 meaning that 27% of any disequilibrium will be corrected annually.

Table 1: Estimated Long Run Coefficients using the ARDL Approach ARDL(1,0,0,3) selected based on Schwarz Bayesian Criterion

| Dependent variable is LNYL<br>38 observations used for estimation from 1966 to 2003 | | | |
|---|---|---|---|
| Regressor | Coefficient | Standard Error | T-Ratio [Prob] |
| LNTL | 0.46211 | 0.11583 | 3.9894[.000] |
| LNRDL | 0.25069 | 0.050201 | 4.9937[.000] |
| LNIEL | 0.20761 | 0.087258 | 2.3792[.024] |
| C | 0.40171 | 0.41948 | 0.95764[.346] |

Table 2: Error Correction Representation for the Selected ARDL Model ARDL(1,0,0,3) selected based on Schwarz Bayesian Criterion

| Dependent variable is dLNYL<br>38 observations used for estimation from 1966 to 2003 | | | |
|---|---|---|---|
| Regressor | Coefficient | Standard Error | T-Ratio[Prob] |
| dLNTL | 0.12528 | 0.049663 | 2.5226[.017] |
| dLNRDL | 0.067961 | 0.023182 | 2.9316[.006] |
| dLNIEL | 0.12495 | 0.063462 | 1.9689[.058] |
| dLNIEL1 | -0.099444 | 0.059639 | -1.6674[.106] |
| dLNIEL2 | -0.15838 | 0.055007 | -2.8793[.007] |
| dC | 0.10890 | 0.10800 | 1.0084[.321] |
| ecm(-1) | -0.27110 | 0.066147 | -4.0984[.000] |
| ecm = LNYL -.46211*LNTL -.25069*LNRDL -.20761*LNIEL -.40171*C | | | |
| R-Squared | .64545 | R-Bar-Squared | .56272 |
| S.E. of Regression | .0097889 | F-stat. F( 6, 31) | 9.1024[.000] |
| Mean of Dependent Variable | .016053 | S.D. of Dependent Variable | .014803 |
| Residual Sum of Squares | .0028747 | Equation Log-likelihood | 126.3791 |
| Akaike Info. Criterion | 118.3791 | Schwarz Bayesian Criterion | 111.8287 |
| DW-statistic | 1.6003 | | |

In short-run the largest proportion of change in labor productivity is explained by the stock of public infrastructure *lnTL*: 1% increase in the stock of public infrastructure will increase the labor productivity in the present period by 0.125%. The effect on *lnRDL* and *lnIEL* is 0.068% and 0.124% respectively.

The lagged coefficients of *lnIEL*; *lnIEL1* and *lnIEL2*, are negative indicating that the economic openness will negatively affect labor productivity in the first and second succeeding years.

The results of diagnostic tests also confirm that the specification of the model is correct. These diagnostic tests are: the Lagrange Multiplier (LM) test for serial correlation, the normality test, the ARCH test and the unit root test of the residuals. Using CUSUM and CUSUM square tests, the stability of the model has been tested and approved.

Figure 2 depicts the actual and fitted values of the lnYL for the long run model. The estimated model perfectly fits with the realized data, as can be seen below.

Figure 2: Actual and fitted values of the lnYL, the long-run model

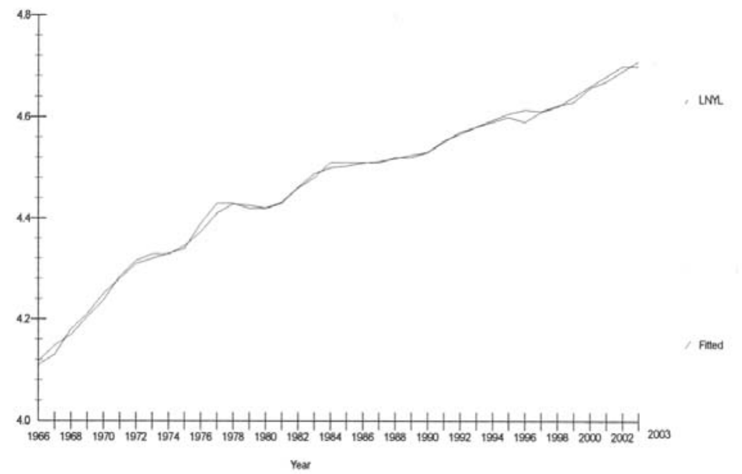
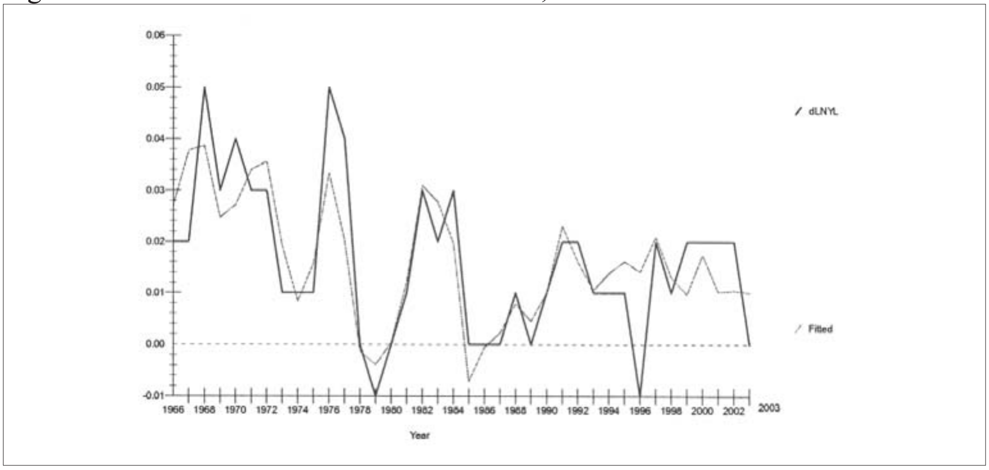



Figure 3 shows the actual and fitted values of lnYL for the error correction model. Again the estimated model corresponds to the actual data.

When looking at economic infrastructure, social/cultural infrastructure, environmental infrastructure and institutional infrastructure, which are the major components of the total infrastructure, we can see that the economic infrastructure is the only proportion of this total which significantly affects the labor productivity[5]. The coefficients of other components are not significant even at 10% level of significancy.

Figure 3: Actual and fitted values of the lnYL, the error correction model




## Conclusion

38 years of observations on labor productivity, stock of public infrastructure and its components (economic public infrastructure, social/cultural public infrastructure, environmental public infrastructure and institutional public infrastructure), economic openness, R&D expenditure, and total hours worked were used in estimating an econometrics model and examining the sources of labor productivity in the Canadian economy. In the short run all three major explanatory variables, which are the stock of public infrastructure, economic openness and R & D expenditure, show positive effects on labor productivity. The first and second lagged values of trade openness, however, indicate of a negative relationship between mid-term economic openness and labor productivity. A negative correction factor confirmed an adjustment period of approximately 4 years for any deviation from the equilibrium status of labor productivity.

The strong relationship between labor productivity and the stock of public infrastructure suggests that the later is the main source of long-run productivity growth. R&D costs and economic openness were also found to have a positive long run relationship with labor productivity. Among all four components of public infrastructure only economic infrastructure was found to effect labor productivity both in the long run and in the short run.

Future works could improve these results by addressing the effect of labor quality on the labor productivity. This goal could be achieved by having a proper proxy for the labor quality.

## NOTES

[1] Harchaoui T. and Tarkhani F. (2005).

[2] Madden G. and Savage S. (1998).

[3] Pesaran and Pesaran(1997).

[4] All empirical estimation was carried out using Microfit econometrics software developed by Professor Pesaran.

[5] With the exception of economic infrastructure all other components of public infrastructure are stationary.

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