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The macroeconomics impact of population growth: Evidence from a panel of Canadian provinces

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Abstract

The federal government has revised upwards its immigration targets in 2022, claiming it was essential to the country's economic growth, a claim made even though few studies directly estimate the effects of such a measure. This paper uses panel data for Canadian provinces from 1981 to 2021 to estimate the macroeconomic effects of faster population growth. The results show that gross domestic product (GDP) per capita falls so significantly in the year of a population shock that total GDP gains are insignificant, which is mainly due to a substantial reduction in labour intensity coupled to a slight decrease in labour productivity. The same shock triggers increased investment in residential and non-residential buildings accompanied by a deterioration of the commercial balance. However, capital intensity does not appear to recover fully in the long term as no significant response in civil engineering or machinery and equipment is detected. The results may help explain why Canada has both the lowest productivity gains in the OECD and the fastest population growth in this group of countries.

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INTRODUCTION

In 2023, Canada's population grew by a record 1.1 million, the fastest annual growth rate (2.9%) since the peak of the post-war baby boom in 1957. Coming on the heels of another year of rapid growth (1.9% between 2021 and 2022), Canada's population has grown by almost 4.9% in just two years (see Figure 1). While the arrival of an unprecedented number of non-permanent residents and the reopening of borders after the COVID crisis are largely responsible for this exceptional population growth, these temporary factors are not the only ones at play. Between 1990 and 2016, the Canadian population grew by around 1.2% per year, and the average population growth scenarios released by Statistics Canada at the time (Bohnert, 2015) projected that this growth rate would slow slightly until 2030. On the contrary, the raising of immigration targets from 0.8% to 1.0% of the Canadian population in the middle of the last decade, and a broadening of the criteria for accepting non-permanent residents, boosted the country's population growth to around 1.5% annually between 2017 and 2019, making Canada the G7 country with the fastest-growing population since 2016.[1] To address the labour shortage, the Canadian government announced on November 1, 2022 that it would further raise the annual target for new permanent residents to 1.2% of the population. This increase, aimed at attracting skilled workers in priority fields, was deemed "...critical to Canada's economic growth" and "key to supporting the economic recovery".[2]

Canada's immigration policy has many objectives[3] but its economic component, which strives to achieve the dual objectives of promoting long-term economic growth while addressing the cyclical needs of the labour market, has always been paramount (Green & Green, 1999). These two objectives sometimes work at odds with each other. Higher immigration thresholds foster economic growth by expanding the pool of available workers, an advantage in the context of chronic low fertility rates. But when unemployment is high, the ensuing increase in labour supply creates additional tensions regarding cyclical needs. Green & Green (2004) point out that, since the 1990s, long-term objectives have taken precedence, as immigration thresholds were raised even at times when the labour market was having difficulty absorbing new arrivals.

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[1] https://www150.statcan.gc.ca/n1/en/daily-quotidien/220209/dq220209a-eng.pdf Only 11 countries have had a population growth exceeding 2.9% in 2022.

[2] Government of Canada, Immigration, Refugees and Citizenship Canada, *2022 Annual Report to Parliament on immigration*, p.9.

[3] Non-economic objectives include namely promoting cultural diversity, protecting Francophone communities living outside of Quebec and ensuring that Canada meets its international commitments to refugees. Without denying their importance, the present study does not deal with these non-economic aspects.

The effect of immigration on the host country has been extensively studied and the subject of several international reviews (Borjas (1994), Kerr & Kerr (2011) Edo et al. (2020)). Despite this abundant literature, Borjas (2019) points out that the direct link between economic growth in the host country and immigration remains poorly researched. Its impact is generally inferred only indirectly through its effects on the labour market or public finances and is sufficiently mixed that no general conclusions can be drawn. In view of this statement, the long-term growth objective pursued by the government cannot be taken for granted. Indeed, while Canada's population is set to grow substantially until at least 2068[4], an anomaly among developed economies, Canada is expected to show the slowest increase in living standards among OECD countries, largely because of the lowest per capita capital stock growth and productivity gains among developed economies (OECD, 2021).

The economic effect of Canada's immigration thresholds has recently been studied by Doyle et al. (2023). They point out that the long-term objective should not be to promote growth in total gross domestic product (GDP), but rather to increase real per capita GDP. Yet, they find that Canada's per capita GDP growth slows when the number of migrants increases. This paper aims to complement their analysis by showing how population growth impacts Canada's short-term macroeconomic performance. To take advantage of the substantial differences in demographic dynamism between Canadian provinces, and at the same time increasing the number of observations, the analysis is carried out on annual panel data from the ten Canadian provinces covering the period 1982 -2021, that is, on 400 observations.

Three types of results are presented, firstly on output, productivity, and employment, then on production factors income and, finally, on the composition of final demand and gross fixed capital formation. The main conclusion is that Canadians' standard of living is lowered in the short term when population growth accelerates, a decline partly explained by a reduction in labour productivity but mostly because of a fall in labour intensity. The results also show that population growth increases the rate of growth in residential and non-residential buildings but causes no reaction to the formation of other forms of physical capital. The paper is structured as follows. The

[4] The pace of population growth accelerated to such an extent that Statistics Canada exceptionally revised its 2018 population projections after only 3 years. The 1.2% immigration rate is part of the high-growth scenarios forecasting that the Canadian population will reach nearly 75 million in 2068, implying to maintain an average annual growth rate of 1.5% since 2021, and would still be growing at this time. Note that the high-growth scenarios also assume a fertility rate of 1.79, well above the historic low of 1.33 observed in 2022, a value rather consistent with a low growth scenario. Population trends in a low-fertility, high-immigration scenario have not been published. See https://www150.statcan.gc.ca/n1/pub/91-520-x/91-520-x2022001-eng.htm for demographic scenario assumptions and results.

next section outlines the theoretical impacts of a population shock on real GDP, factor compensation and the composition of final demand. The third section examines the Canadian literature on the economic impact of immigration. Section four explains the dependent variables while section five presents the results.

WHAT ARE THE THEORETICAL EFFECTS OF A MIGRATION SHOCK?

A migration shock can take two distinct forms: either a level shock producing a temporary jump in the number of migrants, or, as the Canadian government recently decided, a sustained raise in the rate of migration that modifies the population growth rate permanently. As is usual in the literature we will look at the theoretical implications of these shocks with a modified form of the Solow growth model. Since this model is based on a constant exogenous savings rate, the analysis will subsequently be extended to examine how the savings and investment rates could theoretically be affected by this shock. Two types of effects will be distinguished: those that occur initially, which depends on the degree of complementarity or substitutability between factors of production, and those stemming from capital accumulation and the pace of innovation which take place subsequently to determine the long-run dynamic.

Solow's model is built on an aggregate production function (Y) that depends on two factors, capital (K) and labor (L), with constant returns to scale and diminishing marginal returns. Technology (A) is assumed to be neutral in the Harrod sense, meaning that it modifies only the efficiency of labour. At time t we have the relationship:

$$Y_t = F(K_t, A_t L_t) \tag{1}$$

Given that the capital stock is increased by investment (I_t) but is subject to depreciation at a fixed rate δ the equation of motion for capital is:

$$K_{t+1} = K_t + I_t - \delta K_t \tag{2}$$

The number of workers changes over time, as the country's population increases due to natural increase n and net immigration, which is supposed to be a proportion m of total population. Therefore, the equation of motion for labour is:

$$L_{t+1} = (1 + n + m) L_t \tag{3}$$

Labour efficiency A is assumed to grow at an exogenous rate g. Thus:

$$A_{t+1} = (1 + g) A_t \tag{4}$$

Finally, a constant fraction s of output is saved for investment, that is:

$$I_t = sY_t \tag{5}$$

This framework produces unequivocal predictions about the short-term effects of an immigration shock that expands the labour force. The marginal productivity of labour being positive, total output immediately increases. But since capital does not adjust in the current period, the capital available for each worker falls. With both factors being complementary, this lowers the marginal productivity of labour and increases that of capital. Factors being paid at their marginal productivity, the average wage of workers is reduced while firms, which own capital, see their profitability improving. Additionally, the average output per worker $y = Y/L$ decreases. If N is the total population, the effect on GDP per capita Y/N also depends on how the employment to population ratio L/N reacts. If the immigration shock raises L/N then GDP per capita will fall less than average labour productivity, but more if, on the contrary, L/N decreases.

Let's now consider the dynamic effects. The model predicts that the economy converges in the long run to a stable capital to effective labour ratio $\tilde{k} = K/AL$. Assuming a Cobb-Douglas production function $Y_t = K_t^{\alpha}(A_tL_t)^{(1-\alpha)}$ where α is the elasticity of output with respect to physical capital, the production function per effective worker becomes:

$$\tilde{y}_t = A_t\tilde{k}_t^{\alpha} \tag{6}$$

where in equation (6) $\tilde{y}$ denotes output per effective worker. It is easy to show that the long-run stable solution is:

$$\tilde{k}^* = \left(\frac{s}{n+m+g+\delta}\right)^{\frac{1}{(1-\alpha)}} \tag{7}$$

The equilibrium ratio of capital to effective labour is positively related to the savings rate, but negatively affected by the rate of population growth, the rate of capital depreciation and the rate of technological progress.[5] As none of these parameters is affected by an unrepeated population shock, the initial effects, even if they persist over time, will eventually vanish and $\tilde{k}$ will progressively revert to the level it would have maintained in the absence of the shock. However, with a constant savings rate, the speed of this adjustment is so slow that it could take more than a decade for most

[5] In long-term equilibrium, technical progress increases effective labour at the rate g. This implies that output per worker y, real wages w and the capital-labour ratio k also increase at the same rate, while the ratio k/y and the rate of return on capital remain constant.

of the initial effects to disappear. Thus, calling an effect temporary does not mean it is negligible, as a whole generation may be impacted.[6]

The long-run impact of a permanent increase in m is different. Because an increased fraction of investment must be devoted to providing new workers with the same stock of capital as existing workers, this reduces $\tilde{k}^*$ as can be seen equation in 7, which induces a permanent fall in labour productivity and per-capita GDP. The long-run impact of increasing the immigration threshold from 1% to 1.2% as introduced in 2022 can be approximated by inserting plausible parameter values in equation 7. Assuming that the natural population growth rate is currently 0.3%, that the capital depreciation rate is close to Statistics Canada's estimates of 5%, that productivity increases by 1% annually, that the aggregate savings rate is 20% and $\alpha \approx 1/3$, the increase in m of 0,2% would reduce $\tilde{k}^*$ from 4.53 to 4.35. All other things being equal, a fall of this magnitude (4.0%) would permanently reduce per capita GDP by around 1.34% in the long run. This reduction could be avoided by increasing the savings rate, a change that would however have an uncertain impact on per capita consumption.[7]

Figure 2 shows the time-path of changes in per-capita GDP predicted by the Solow model following both types of shocks. At impact, per-capita GDP falls by a meagre 0.067 % (one-third of 0.2 %). In the case of a one-time increase in population, the GDP begins the following year its slow return to its pre-shock value, with a remaining impact after 30 years of 0.017 %. But with a permanent shock, per-capita GDP continues to decline year after year. After 30 years it has become 1% lower than without the shock and pursued its steady decline towards its final reduction of 1.34%. It is important to point-out, as shown in Figure 3, that despite the negative permanent impact on per-capita GDP, total GDP grows faster, as the larger pool of workers more than compensate the reduction in per-capita GDP. This also shows the pernicious impact on the standard of living of a faster growing population, as its full impact takes time to materialize while total GDP growth accelerates.

The model of Solow supposes that the savings rate is exogenous but economic theory offers two different reasons why the savings rate may react to the population growth rate. Firstly, according to the life-cycle theory (Modigliani, 1966), working people save to finance consumption during

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[6] If the savings rate is constant, a fraction of roughly $(\alpha - 1)(n + m + g + \delta)$ of the deviation from the long-term solution is closed each period. With current plausible annual values for Canada being $n + m \approx 0.015$, $g \approx 0.01$ and $\delta \approx 0.05$, only about 5% of the deviation to long-run equilibrium would disappear each year. At this rate it takes 14 years to close half of the decline in the capital-labour ratio, 28 years to make up ¾, and so on.

[7] As is well known from the Golden Rule, raising the savings rate increases consumption only if this rate is lower than the elasticity of production with respect to capital.

retirement. All other things being equal, the higher the proportion of working age in the total population, the greater the aggregate savings. In Modigliani's basic model, an increase in the population growth rate has an unambiguously positive impact on the aggregate savings rate, as it increases the ratio between young working people and retirees. In practice, because children are dependent on their parents at birth, the effect on the savings rate is more nuanced and depends on the age structure of the population (Cook, 2005).

The other reason arises because of the impact of population growth on the rate of return on capital. Regardless of whether the shock is temporary or permanent, both initially boost the rate of return on capital due to the immediate reduction in the capital-labour ratio. Since the cost of actual consumption is the return on capital, consumption becomes more expensive and immediately falls in favor of investment, thus accelerating the return to long-term equilibrium. If the initial shock is temporary, the rate of return on capital and the fraction of income consumed will gradually return to their pre-shock levels.[8] But in the case of a lasting increase in the population growth rate, the fraction of output consumed remains persistently lower as the rate of return on capital rises permanently (Alvarez-Cuadrado, 2019).

In short, a population shock, be it temporary or permanent, is expected to reduce the fraction of GDP devoted to consumption and increase the proportion allocated to investment. The capital dilution effect will eventually disappear if the rise in $n + m$ produces a long-term proportional rise in the capital stock. That requires that the long-term elasticity of the capital stock in relation to population must be equal to 1. Expressed as a proportion of annual output, that means a cumulative impact on investment equals to the existing capital/GDP ratio.[9] Besides the short-term movements arising from the temporary falls in GDP during the recessions (1981-82, 1990-92, 2008 and 2020-21), this proportion has varied little in Canada since 1981 (see Figure 4), remaining at around 310% of output, or approximately 330% if the value of intellectual property is included. That means that for each 1% increase in population, the investment required to keep the capital-labour ratio at its prior value cumulates to a little more than 3% of GDP.[10] Given the identity between production

[8] The effect just described can be traced in the well-known Ramsey-Cass-Koopmans model on the stable arm moving the economy towards its long-term equilibrium.

[9] If the stock of capital grows at the rate $n + m + g$ then $K_{t+1} = (1 + n + m + g)K_t$. By equation (2) we therefore have $(1 + n + m + g)K_t = K_t + I_t - \delta K_t$, which can also be written $I_t = (n + m + g + \delta)K_t$. Dividing by GDP the equation becomes $I_t/Y_t = (n + m + g + \delta)K_t/Y_t$. For the capital dilution effect to disappear in the long run, no effect on GDP shall persist which means that $\partial Y/\partial(n + m) = 0$. Under this condition the cumulative sensitivity of investment as a proportion of GDP $\partial(I/Y)/\partial(n + m) = K/Y$.

[10] These values are national averages that conceal substantial provincial differences as the oil-rich provinces of Alberta, Saskatchewan, and Newfoundland-Labrador have a capital intensity considerably larger than the other seven provinces.

and final expenditure, a fall of the same order of magnitude is required in consumption in a closed economy. In an open economy, foreign savings is the likely source of financing for additional investment, so that a fall in net exports should be observed.

The breakdown of capital into its various components shows that engineering construction ranks 1st in importance (on average 103% of GDP over the period 1981-2021), closely followed by residential buildings (95%), non-residential buildings (70%), machinery and equipment (44%) and, finally, intellectual property (19%). This composition of the capital is instructive because it shows how much investment is needed in each component to keep the composition of the capital stock unchanged as population rises. A long-run impact on a specific component lower than its current capital-output ratio indicates that this part of the capital stock is suffering from a permanent dilution effect.

Another impact of immigration on the macroeconomic performance is its contribution through human capital (Dolado et al. ,1994). When the educational level and professional qualifications of immigrants are higher, on average, than those of the native population, immigration contributes to increasing the average productivity of labour and capital. If they are lower however, immigration accentuates the loss of labour productivity caused by the reduction in the capital-labour ratio. When workers have different skill levels, immigration may also impact the wage distribution. Workers with skills complementary to those of immigrants should see their pay increase, as the demand for their service will rise, while workers with substitutable skills will be disadvantaged. (Longhi et al., 2008). If most immigrants are low-skilled, in addition to lowering average human capital, immigration is likely to result in greater income inequality since low qualified workers are paid less (Busch et al. ,2020). Since Canada's scoring system of immigration applications favors applicants with a higher educational level, the earnings of the highly skilled can be expected to fall, while those of the low-skilled to rise, thereby potentially reducing income inequality (Aydemir & Borjas, 2006). Yet, according to Gu (2023), the immigrant population in Canada had in 2019 an average human capital 14% lower than the average human capital of the Canadian-born population.

Distributive analysis based solely on workers' compensation is incomplete if one does not also consider the effect of a population shock on capital income. As a result of the expected rise of the rate of returns on capital, owners of businesses and rental properties, as well as owner-occupiers, should see their capital income and wealth increase. According to the life-cycle predictions, the largest holders of capital are those close to retirement age. On the other hand, since there are few owners among the young, immigration is likely to be unfavorable to them. Note that this distribution of gains and losses in the population may shape attitudes towards immigration (Söllner, 1999), meaning that the generally favourable position of businesses at higher immigration could be due to their anticipated gains in profitability.

A final potential effect of the human capital of migrants on long-term dynamics is their contribution to innovations. Several studies (Hunt & Gauthier-Loiselle (2010), Burchardi et al., (2020), Terry et al. (2022)) conclude that the US states with higher immigration experiences a faster growth rate of productivity. In the same vein, Boubtane et al. (2016) conclude that because of this impact on innovation, a permanent increase in migration flows improved the GDP per worker in OECD countries, as the present value of long-term gains from a faster rate of innovation exceeds the short-term costs associated with a migration shock.

CANADIAN STUDIES

Several studies have been carried out on the economic impact of immigration in Canada. An excellent overview was conducted by Boudarbat & Grenier (2014), and only a partial presentation is made here. The principal subject of these studies is the labour market integration of immigrants. The unequivocal conclusion is that they have a more difficult career path than natives (Hum & Simpson, 2004), a discrepancy that has widened for more recent immigrants (Akbari & Haider, 2018; Baker & Benjamin, 1994), the likely result of a growing lack of recognition of skills and diplomas acquired abroad.

The effect on Canadian GDP was investigated in two different ways. Using an overlapping-generation model, Fougère et al. (2004) find a positive impact to GDP per capita, mainly because of an increase in the proportion of working-age population. Dungan et al. (2013) use a macroeconomic model to simulate the effect of an increase of 100,000 immigrants per year for 10 years. They conclude that, due to immigrants' difficulties in integrating the labour market, GDP per capita would fall slightly, but would become slightly higher at the end of the simulation period if their employment prospects matched the Canadian average. Note that this gain would arise not because of the increased weight of the working-age population as in Fougère et al. but rather from an increased demand in sectors with higher-than-average productivity. Akbari & Haider (2018) estimate a production function in which the levels of education attained by the Canadian-born population and the immigrant population appear as proxies for human capital. They conclude that immigrants' human capital stock contributes to economic growth, especially for the most populous provinces, but immigrants' human capital has less influence at a given level of education, either because of a lack of diploma recognition or other skills not associated with diplomas.

The impact of immigration on innovation in Canada has been studied by Partridge & Furtan (2008) and they find that highly skilled immigrants contribute significantly to innovation in their host province. While confirming the direction of these effects in 98 Canadian municipalities, Blit et al. (2020) finds that this effect is very modest and considerably smaller than in the USA, possibly because of the small proportion of skilled immigrants working in high-tech sectors.

In contrast to these rather favourable results, Doyle et al. (2023) conclude, based on annual national data, that increases in Canada's immigration levels were followed by a slowdown in per capita GDP growth the following year, an effect that gradually diminishes thereafter. In addition, they point out that even though the immigration rate is significantly higher in Canada than in the U.S., the latter has significantly higher productivity gains and per capita investment than Canada. Perhaps because of our industrial structure, the expected gains in innovation do not seem to be materializing to any significant extent in Canada. They related this also to the fact that Canadian workers have a lower level of productive capital, an observation also made by Bobson and Rafale (2023) who estimated that Canadian workers dispose of no more than 65 % of the average per-worker business capital available in average in the OECD countries.

The impact of immigration on the housing market has also been analyzed. Using census data Akbari & Aydede (2012) find a positive but small impact of immigration on housing prices. Using instead a time-series approach on provincial data, Latif (2015) detects a positive long-term effect on housing rents. Nistor & Reianu (2018), for their part, use data from Ontario's ten largest census metropolitan areas and conclude that immigration is one of the three main factors, along with average income and interest rates, that have driven up housing prices in Ontario.

DESCRIPTION OF VARIABLES

Data were constructed for the ten Canadian provinces, thus excluding territories for which several data were not available. The dependent variables are grouped into three main categories: macroeconomic performance, income from factors of production and, finally, the composition of final demand and capital formation. The list of variables is shown in Table 1, while the source of the data and the way in which they were constructed are presented in Appendix 1. Since the National Accounts data for the provinces start in 1981, and the data for 2022 are incomplete, the database covers the period 1981-2021, i.e. 41 years, allowing 40 years of estimation given the calculation of rates of change.

Table 1: List of dependent variables

Catégories	Description of variables
Macroeconomic performance	• Real gross domestic product per capita • Hourly labour productivity • Hours worked per capita. • Total employment per capita
Factor remuneration	• Employee compensation (consumer prices) • Employee compensation (producer prices) • Rate of return on capital • Real housing prices
Shares of final demand	• Consumption • Gross fixed capital formation • Residential buildings • Non-residential buildings and structures • Machinery and equipment • Net exports
Capital formation	• Physical capital • Residential buildings • Non-residential buildings • Machinery & equipment • Engineering construction

Given the objective of documenting how population growth impacts the economy, the meaning and relevance of the macroeconomic performance variables are clear and require little explanation. It should only be pointed out that, to facilitate consistency with GDP per capita, employment is also expressed as a percentage of total population, rather than in proportion to the population aged 15 and older, which is the usual definition of the employment rate.

The variables in the second category require further clarification. Employee compensation is the real cost of work on an hourly basis. The nominal hourly labour cost was calculated by dividing employee compensation in the national accounts by the number of hours worked, and then converted in real value based on two different price indexes. Using the provincial consumer price (CPI), it measures workers' average purchasing power. If we rather use the GDP implicit price index, workers' compensation is expressed as a proportion of the value of goods and services produced, a measure relevant for employers to know the average labour cost of goods and services obtained per hour worked. Both price indices diverge when the price of capital goods evolves differently from that of consumer prices and, more importantly, when the terms of trade fluctuate. Given that the provinces have substantially different industrial structures, the two wage measures are likely to behave very differently between provinces. It should be remembered also that employee compensation should be more sensitive to output prices than to consumer prices if the supply of labour has a lower elasticity than its demand. As for the rate of return on capital, it is the ratio between gross operating surplus of societies during the current year and the capital stock at the end of the previous year.

The third part, studying the response of capital formation to the rate of population growth, follows two approaches. The first estimates how the shares of final demand in GDP changes in reaction to population growth. The components considered are consumption, gross fixed capital formation (GFCF) and net exports. To see if the composition of physical goods is modified by population growth, GFCF was further disaggregated into three components: residential buildings; non-residential buildings and structures; machinery and equipment. Note that net exports are needed because for small open economies, it is likely to be foreign savings that meet domestic financing needs. In such a case, a rise in investment should lead to a fall in net exports, not consumption.

The second approach takes as dependent variables the rate of change in physical capital, which will provide a direct measure of the elasticity of capital growth to population increase. This time, physical capital is decomposed even more finely since, in addition to residential buildings and machinery and equipment, non-residential structures is broken down into engineering construction and non-residential buildings.[11]

THE ECONOMETRIC MODEL

The aim of the present work is not to evaluate the effect of immigration per se, but rather to assess the macroeconomic implications of a policy aimed at making the Canadian population to grow faster. For this reason, the equations will use the current population growth rate in province *j* ($POPG_{jt}$) as the variable of interest. To facilitate the comparison of effects between equations, a common structure has been adopted wherever possible. This structure is based on the two-factor production function, to which control variables are added to capture cyclical effects. Thus, each equation also includes the growth rate of the capital stock in the previous period, noted KG_{t-1}, to capture the effect of an increased supply of capital. As for the business cycle, it is measured by two variables. One, related to national economic conditions, is the previous year's difference between the yield on 3-month Canadian government treasury bills and that on 10-year federal bonds ($YIELD_{t-1}$). This choice is based on the numerous works (Chinn & Kucko, 2015; Harvey, 1997; Hu, 1993) showing that the slope of the yield curve is a very good, and most likely the best,

[11] The reason for this more detailed decomposition is that final demand was taken from Table 36-10-0222-01 which provides an aggregate for non-residential structures while non-residential capital stock data come from Table 36-10-0096-01. In this latter table, non-residential structures are decomposed into non-residential buildings and engineering construction.

predictor of the following year's GDP growth rate. As for the second variable, it is well established that terms-of-trade shocks have a significant impact on Canadian economic conditions and real income growth (Baldwin & Macdonald, 2012; Cao & Kozicki, 2017), and that provinces react differently to these national shocks (Lefebvre & Poloz, 1998). To add a provincial dimension to economic conditions, the variation in each province's terms of trade ($TRADE_{jt}$) was included. [12]

For each variable, if *j* denotes the province and *t* the period, the basic econometric model is:

$$Y_{j,t} = \beta_1 + \beta_2 POPG_{j,t} + \beta_3 KG_{j,t-1} + \beta_4 YIELD_{t-1} + \beta_5 TRADE_{j,t} + \alpha_j + u_{j,t}, j = 1, \ldots, N \text{ et } t = 1, \ldots, T \qquad (8)$$

In this equation α_j is a fixed effect per province, while $u_{j,t}$ is the random shock affecting province *j* at time *t*. The fixed-effect model was chosen both because the Hausman test rejected the random-effect model in most equations, and because this specification is better suited to the structure of the model. Since there is a strong instantaneous correlation between the provincial residuals, the estimation method chosen is that of seemingly unrelated regressions (SUR). In addition, because of the expected heteroscedasticity arising from population differences between provinces, covariances were corrected by the White method applied to cross-sections.

Two other problems must also be addressed: the non-stationarity of variables and the endogeneity of population growth. To avoid the problem of spurious correlations between non-stationary variables, the following variables have been made stationary by taking their growth rates: population, real GDP per capita, hourly labour productivity, hours worked per person, the two measures of employee compensation, real housing prices and the various components of the capital stock. The effect of population growth on these variables will therefore have the dimension of an elasticity. For employment as a proportion of population and the rate of return on capital, stationarity has been obtained by simply taking their difference, so that the effect of population will have to be interpreted as a semi-elasticity.

For the equations explaining the rate of change in the stock of capital a change in the specification was required. Indeed, since we want to explain not only total capital formation but also its components, it would be inappropriate to use the previous year's growth rate in total capital stock as the explanatory variable for all equations. Thus, $KG_{j,t-1}$ was replaced by the lagged value of the

[12] Changes in commodity prices, particularly those of oil and gas, are the main source of variations in the Canadian terms of trade variations. The concentration of oil and gas production in Alberta, Saskatchewan, and Newfoundland-Labrador, combined with the high variability in the price of these resources, is the main factor behind the expected considerable differences in the behaviour of the two real wage series at provincial level and the specificity of provincial terms of trade shocks.

dependent variable, which is the growth rate of each component of the capital stock. This solution offers the additional advantage of facilitating the calculation of the dynamic effects associated to shocks on the explanatory variables. The econometric model for the growth rate of the capital stock is therefore:

$$Y_{j,t} = \alpha_1 + \alpha_2 POPG_{j,t} + \alpha_3 YIELD_{t-1} + \alpha_4 TRADE_{j,t} + \alpha_5 Y_{j,t-1} + \alpha_j + u_{j,t},\ j = 1, \ldots, N \text{ et } t = 1, \ldots, T \quad (9)$$

For final expenditure shares a different approach had to be followed. It is these shares, and not their variation, that are potentially linked to the population growth rate. It was unclear if the shares are stationary as the various stationarity tests led to conflicting conclusions.[13] Yet, when estimating in level, a high degree of first-order autocorrelation of the residuals was present. To deal with this while at the same time estimating in line with theory, the lagged value of the dependent variable was added to capture the possible unit root and eliminate the persistence of residuals. Also, a deterministic trend variable ($TIME_t$) was introduced to capture a possible trend drift. The empirical model of final demand shares is therefore:

$$Y_{j,t} = \gamma_1 + \gamma_2 POPG_{j,t} + \gamma_3 KG_{j,t} + \gamma_4 YIELD_{t-1} + \gamma_5 TRADE_{j,t} + \gamma_6 Y_{j,t-1} + \gamma_7 TIME_t + \alpha_j + u_{jt},\ j = 1, \ldots, N \text{ et } t = 1, \ldots, T \quad (10)$$

The other problem is the endogeneity of population. People migrate to places offering the best employment and income opportunities. In Canada, inter-provincial migration is greatest towards provinces with low unemployment (Bernard et al., 2008; Finnie, 2004) and high wages(Chan & Morissette, 2016). Given this, estimating by ordinary least squares (OLS) the impact of $POPG_t$ on macroeconomic variables positively correlated with income or employment will lead to an overestimation of the true impact of $POPG_t$. To counter this problem, the equations have also been estimated using two-stage least-squares (TSLS) using the population growth rate of the previous period $POPG_{t-1}$ as instrument for $POPG_t$. The degree of dissimilarity between both methods will be indicative of the extent of the endogeneity bias. Note that the usual conditions for validity and exogeneity were satisfied since $POPG_{t-1}$ is highly correlated with $POPG_t$ (0.89) and was found to be independent of the OLS residuals in the various equations.

THE RESULTS

Let's first consider the macroeconomic performance variables in Table 1. It can immediately be seen that the OLS estimates of *POPG* are considerably higher in the GDP per capita, hours worked

[13] As example of conflicting conclusion let consider that for the consumption share equation, assuming independence, the Pesaran, ADF and PP tests do not reject stationarity, while the Levin, Lin & Chu test does. Assuming dependence, the Bai and Ng test finds non-stationarity.

and employment equations, a confirmation that the endogeneity bias is quite important. Indeed, in the real GDP per capita equation this coefficient is -0.56, and -1 is outside the confidence interval, implying that the immediate impact on total GDP is statistically significant. But the TSLS coefficient is instead -0.86, again significant at the 1% threshold, but the value of -1 lies within the confidence interval. After correcting for the endogenous response of population to improvement in income opportunities, one cannot reject the hypothesis that in the year of impact, real total GDP growth does not react to an exogenous rise in population. The same equation also shows, unsurprisingly, a significant positive impact of the Canadian business cycle while the positive effect of provincial terms of trade is not statistically significant.

The following three equations breaks down the effect of *POPG* on real GDP into changes in labour productivity and two measures of labour intensity. With OLS, since hours worked per capita do not fall while the employment rate rises slightly, the fall in per capital GDP arises solely from an estimated reduction (-0.414) in labour productivity, a conclusion to take with caution however as the regression for labour productivity is not significant. With TSLS however, although *POPG* maintains its significant negative impact (-0.437) on labour productivity, it also leads to a substantial and statistically significant reduction in labour intensity. A 1% increase in population growth reduces per capita hours worked by 0.704%, two-third of which due to a fall of 0.447 percentage point of the employment to population ratio. Note that $YIELD_t$ has a significant positive effect (at the 1% level) on hours and employment while TRADE's effect, also positive on both variables, is significant at the 1% threshold for hours but only at the 10% threshold for employment. Finally, the variation in the capital stock is not significant in all four equations. In short, the absence of correction for endogeneity of population may lead to the erroneous conclusion that, apart from a fall in productivity, the labour market can absorb the population shock without any deterioration in prevailing labour market conditions. Once endogeneity is corrected, employment in proportion to population significantly falls, leading to an important drop in per capita GDP.

Table 1: Macroeconomic performance

Ordinary least-squares				
Variable	**Per-capita GDP**	**Labour productivity**	**Per-capita hours**	**Per-capita employment**
C	0.016*** (0.005)	0.013*** (0.003)	0.004 (0.005)	0.002 (0.003)
$POPG_t$	-0.559*** (0.207)	-0.414** (0.195)	-0.105 (0.174)	0.069** (0.031)
KG_{t-1}	-0.173 (0.104)	0.119 (0.099)	-0.316*** (0.110)	-0.146 (0.035)
$YIELD_{t-1}$	0.405** (0.152)	-0.064 (0.103)	0.441** (0.170)	0.297** (0.121)
$TRADE_t$	0.014 (0.032)	-0.051* (0.029)	0.067*** (0.018)	0.018* (0.010)
Weighted R^2	0.083	0.037†	0.116	0.142
Two-stage least-squares				
Variable	**Per-capita GDP**	**Labour productivity**	**Per-capita hours**	**Per-capita employment**
C	0.016*** (0.005)	0.013*** (0.003)	0.004 (0.005)	0.004 (0.004)
$POPG_t$	-0.857*** (0.293)	-0.437** (0.216)	-0.704*** (0.210)	-0.447*** (0.099)
KG_{t-1}	-0.088 (0.123)	0.124 (0.095)	-0.144 (0.114)	-0.049 (0.058)
$YIELD_{t-1}$	0.435*** (0.148)	-0.064 (0.103)	0.463*** (0.168)	0.259** (0.118)
$TRADE_t$	0.026 (0.034)	-0.055* (0.029)	0.073*** (0.019)	0.022* (0.012)
Weighted R^2	0.094	0.039†	0.100	0.117

Equations were estimated with Eviews with the following options: fixed cross section effect, SUR selected for cross-section correlated disturbance and White cross-section correction for heteroscedasticity. Standard errors are between brackets. Coefficient significances are marked at the 10 % (*), 5 % (**) and 1 % (***) levels. The symbol † is used when the equation is not statistically significant.

Table 2: Factors income and housing price

Ordinary least-squares				
Variable	**Labour Income (CPI)**	**Labour Income (GDP deflator)**	**Rate of return on capital**	**Real housing price**
C	0.005 (0.005)	0.008* (0.004)	0.004*** (0.001)	-0.001 (0.010)
$POPG_t$	0.407** (0.189)	0.337* (0.188)	0.050 (0.068)	4.006*** (0.399)
KG_{t-1}	0.172* (0.092)	0.215* (0.107)	-0.225*** (0.039)	-0.820*** (0.172)
$YIELD_{t-1}$	-0.152 (0.138)	-0.243* (0.145)	0.081** (0.036)	0.911* (0.475)
$TRADE_t$	-0.019 (0.018)	-0.530*** (0.023)	0.144*** (0.011)	0.099** (0.035)
Weighted R^2	0.054	0.605	0.569	0.237
Two-stage least-squares				
Variable	**Labour Income (CPI)**	**Labour Income (GDP deflator)**	**Rate of return on capital**	**Real housing price**
C	0.006 (0.004)	0.009** (0.004)	0.004*** (0.001)	0.006 (0.010)
$POPG_t$	0.043 (0.228)	-0.075 (0.231)	0.121 (0.092)	1.947*** (0.542)
KG_{t-1}	0.257*** (0.090)	0.306*** (0.111)	-0.237*** (0.040)	-0.405** (0.199)
$YIELD_{t-1}$	-0.155 (0.140)	-0.253* (0.139)	0.084** (0.036)	0.809 (0.522)
$TRADE_t$	-0.016 (0.018)	-0.525*** (0.023)	0.143*** (0.011)	0.125** (0.049)
Weighted R^2	0.048†	0.596	0.567	0.153

Equations were estimated with Eviews with the following options: fixed cross section effect, SUR selected for cross-section correlated disturbance and White cross-section correction for heteroscedasticity. Standard errors are between brackets. Coefficient significances are marked at the 10 % (*), 5 % (**) and 1 % (***) levels. The symbol † is used when the equation is not statistically significant.

The impacts on factor income and housing price are shown in Table 2. Let's look first at the effect of *POPG*. Contrary to the presumed negative impact on labour compensation, the OLS coefficients rather exhibit a positive effect on both consumer and producer real wages, effects which are reduced and rendered non-significant when estimated by the TSLS. The impact on the rate of return on capital is also positive but not statistically significant, either estimated by OLS or by TSLS. Note that *KG*'s impact is in line with theoretical expectations, significantly increasing the remuneration of labour and reducing that of capital.[14] As to the variables related to the business cycle, they have mixed effect. *YIELD* has a slightly negative impact on labour compensation, while *TRADE* has a very strong negative impact on producer real wages. As for the rate of return on capital, both *YIELD*

[14] Once again, it should be noted that the equation of compensation as a function of CPI is not significant, making it difficult to draw conclusions on a single coefficient.

and *TRADE* have a statistically significant positive effect while the impact of *KG* is statistically negative. It is interesting to contrast the negative effect of *TRADE* on employee compensation with its positive impact on the rate of return on capital. Clearly, an increase in the price of exports improves firms' profitability in the short term, consistent with output prices rising faster than nominal wages. At to real housing price, the last equation shows that population growth has a highly significant positive impact, with the OLS coefficient (4.00) being twice the value estimated by TSLS (1.97). Housing price also reacts positively to *YIELD* and *TRADE* while the impact of *KG* is negative, as might be expected as part of capital growth rises the supply of residential capital.

The impacts on the composition of final demand are presented in Table 3. Let's start by observing that even though the coefficient of the lagged dependent variable is consistently large, the unit value is rejected in all equations, an indication that estimating without differencing was adequate. Looking more specifically at the effect of population growth, a 1 percent increase in population growth raises the share of fixed capital investment by 0.41 percentage points (significant at 5%), while reducing that of net exports by a similar proportion (-0.49). This increased share of investment indicates that the speed of adjustment of capital to its long-term equilibrium value is faster than the theoretical path suggested by the Solow model. If we now turn our attention to the different components of capital, we find that with TSLS, only the share of residential buildings shows a statistically significant reaction (0.17) to *POPG.*

Some other observations can be made about final demand shares. Without great surprise, the share of gross fixed capital formation is procyclical while that of consumption and net exports are counter-cyclical, a predictable consequence of the larger cyclical volatility of investment and the positive marginal propensity to import. We also note that a change in the terms of trade reduces the share of all components of domestic final demand, a likely consequence of an improvement in the value of the commercial balance. Finally, lets notice that there is a positive trend in gross fixed capital formation but a statistically negative trend for machinery and equipment. It is worth noting that, at the Canadian level, these investments represented an average of 6% of GDP between 1980 and 2000, whilst since 2015 they've averaged just 3.5%.

Table 3: Final demand shares of GDP

Ordinary least-squares						
Variable	**Consumption**	**Physical capital**	**Residential buildings**	**Non-residential structures**	**Machinery & equipment**	**Net exports**
C	0.081*** (0.026)	0.054*** (0.009)	0.007*** (0.002)	0.010*** (0.002)	0.019*** (0.002)	-0.009* (0.005)
$POPG_t$	-0.015 (0.150)	0.721*** (0.114)	0.300*** (0.037)	-0.021 (0.107)	0.128*** (0.039)	-0.575** (0.245)
KG_{t-1}	0.029 (0.101)	0.129 (0.117)	-0.114*** (0.018)	0.293*** (0.062)	-0.015 (0.026)	0.287* (0.150)
$YIELD_{t-1}$	-0.241*** (0.044)	0.149*** (0.053)	0.048 (0.033)	0.014 (0.024)	0.085** (0.037)	-0.242** (0.113)
$TRADE_t$	-0.359*** (0.017)	-0.044*** (0.015)	-0.015*** (0.003)	-0.021** (0.010)	-0.006 (0.005)	0.388*** (0.024)
LAG of dep.	0.906*** (0.028)	0.691*** (0.049)	0.859*** (0.038)	0.648*** (0.048)	0.647*** (0.040)	0.868*** (0.024)
TIME	0.012* (0.006)	0.027*** (0.007)	0.007 (0.004)	0.012*** (0.003)	-0.019*** (0.003)	0.004 (0.012)
Weighted R^2	0.984	0.840	0.892	0.856	0.765	0.969
Two-stage least-squares						
Variable	**Consumption**	**Physical capital**	**Residential buildings**	**Non-residential structures**	**Machinery & equipment**	**Net exports**
C	0.076*** (0.025)	0.054*** (0.010)	0.006*** (0.002)	0.010*** (0.002)	0.019*** (0.002)	-0.009* (0.005)
$POPG_t$	0.119 (0.165)	0.408** (0.187)	0.171*** (0.049)	-0.015 (0.087)	0.039 (0.049)	-0.493* (0.292)
KG_{t-1}	0.016 (0.100)	0.234* (0.128)	-0.084*** (0.020)	0.292*** (0.057)	-0.000 (0.028)	0.265 (0.169)
$YIELD_{t-1}$	-0.233*** (0.043)	0.183*** (0.048)	0.046 (0.031)	0.015 (0.024)	0.089** (0.037)	-0.238** (0.022)
$TRADE_t$	-0.361*** (0.017)	-0.038** (0.021)	-0.014*** (0.003)	-0.021** (0.010)	-0.005 (0.005)	0.388*** (0.024)
LAG of dep.	0.910*** (0.028)	0.684*** (0.054)	0.880*** (0.041)	0.654*** (0.046)	0.663*** (0.039)	0.866*** (0.024)
TIME	0.011* (0.006)	0.017** (0.007)	0.007* (0.004)	0.012*** (0.003)	-0.018*** (0.004)	0.003 (0.013)
Weighted R^2	0.985	0.827	0.879	0.856	0.759	0.969

Equations were estimated with Eviews with the following options: fixed cross section effect, SUR selected for cross-section correlated disturbance and White cross-section correction for heteroscedasticity. Standard errors are between brackets. Coefficient significances are marked at the 10 % (*), 5 % (**) and 1 % (***) levels.

Table 4 shows how the growth rate of the different components constituting physical capital reacts to *POPG*. The capital dilution effect can be avoided only if the capital stock grows in the same proportion as the population, a condition requiring a long-run elasticity of the capital stock to population, given by $\alpha_2/(1-\alpha_5)$, to be equal to one. Once more, because the endogeneity of population creates substantial differences between OLS and TSLS estimates, our discussion will focus only on the latter. Let us recall that non-residential structures are broken down into non-residential buildings and engineering construction.

Table 4: Elasticity of physical capital creation to population growth

Ordinary least-squares					
Variable	**Physical capital**	**Residential buildings**	**Non-residential buildings**	**Machinery & equipment**	**Engineering construction**
C	0.002** (0.001)	0.004*** (0.001)	0.003*** (0.001)	-0.003** (0.001)	0.003*** (0.001)
$POPG_t$	0.267*** (0.049)	0.421*** (0.073)	0.185*** (0.057)	0.170** (0.085)	0.094 (0.092)
$YIELD_{t\text{-}1}$	0.061*** (0.017)	0.084* (0.044)	0.003 (0.032)	0.197*** (0.064)	0.077*** (0.023)
$TRADE_t$	0.016*** (0.006)	0.010** (0.005)	0.013 (0.010)	0.058*** (0.015)	-0.006 (0.007)
LAG of dep	0.775*** (0.028)	0.700*** (0.033)	0.785*** (0.032)	0.836*** (0.028)	0.761*** (0.035)
Weighted R2	0.839	0.819	0.767	0.759	0.696
Two-stage least-squares					
Variable	**Physical capital**	**Residential buildings**	**Non-residential buildings**	**Machinery & equipment**	**Engineering construction**
C	0.002** (0.001)	0.004*** (0.001)	0.003*** (0.001)	-0.001 (0.001)	0.003** (0.001)
$POPG_t$	0.121** (0.062)	0.224*** (0.073)	0.161*** (0.057)	-0.176 (0.112)	0.113 (0.100)
$YIELD_{t\text{-}1}$	0.063*** (0.016)	0.084** (0.039)	-0.001 (0.032)	0.196*** (0.067)	0.082*** (0.023)
$TRADE_t$	0.018*** (0.006)	0.012*** (0.004)	0.013 (0.010)	0.061*** (0.016)	-0.007 (0.008)
LAG of dep	0.814*** (0.032)	0.757*** (0.036)	0.786*** (0.032)	0.867*** (0.028)	0.758*** (0.035)
Weighted R2	0.823	0.788	0.763	0.756	0.698

Equations were estimated with Eviews with the following options: fixed cross section effect, SUR selected for cross-section correlated disturbance and White cross-section correction for heteroscedasticity. Standard errors are between brackets. Coefficient significances are marked at the 10 % (*), 5 % (**) and 1 % (***) levels.

In addition to reacting positively to *YIELD* and *TRADE*, the physical capital stock shows a instantaneous elasticity to *POPG* of 0.121, peaking at only 0.65 in the long run, suggesting that the increase in the population growth rate permanently reduces the capital-labour ratio. When we look at the components of the capital stock, residential buildings turn out to have both the highest immediate (0.224) and long run (0.925) responses to *POPG*. Residential buildings react also positively to *YIELD* and *TRADE*. Non-residential buildings, while reacting less to *POPG* (0.161) than residential structures, are more sensitive than the total physical capital stock. Its long-term elasticity (0.752) also lies between the values estimated for the stock of physical capital and for residential capital. On the other hand, is shows no sensitivity to economic conditions. As for engineering construction and machinery and equipment, although both react to economic conditions, their sensitivity to *POPG*, or should we say lack of sensitivity, is surprising. Indeed, the estimated elasticity (0.113) of engineering works to *GPOP*, although close to the value estimated for the total physical capital, is non-significant, while that of machinery and equipment is slightly negative and non-significant.

These estimates can be used to calculate the dynamic response of physical capital and residential and non-residential structures, as shown in figure 5. The figure shows that adjustment of capital towards its long-term value is considerably faster than the theoretical speed predicted by the Solow model. Far from the expected sixteen years needed to close half of the physical capital gap created by the population shock, this result is achieved in five years, and only 20% of the gap remains after eight years. In the case of residential buildings, the adjustment is even faster, with comparable results achieved after three and five years respectively.

There is no easy explanation for the lack of response of equipment and machinery, which component represent a declining share of investment over the last forty years. As to engineering construction, the low level of public infrastructure is a long-recognized problem in Canada (Mackenzie, 2013). The poor state of Canadian public infrastructures is largely documented (see Card, 2019) to the extent that a national plan to increase investment in infrastructures was launched in 2016 (Government of Canada, 2016). The present analysis suggests that part of the reason for the lack of investment in equipment and in infrastructure is that capital formation in Canada has become skewed towards the construction of buildings, and mainly residential building, as the country tries to accommodate the housing needs of a faster growing population. This is not likely to change soon given that, faced with the unprecedented housing shortage, the federal and provincial governments have recently added incentives to accelerate housing starts.

SENSITIVITY ANALYSIS

Because of the growing weight of the senior population, whose participation rate is low, it is possible that total population growth was a poor proxy for labour supply growth. To check the importance of this issue, the equations were re-estimated using instead the growth rate in the working-age population, that is, between 15 and 64 years old. The TSLS results, presented in appendix 3, show few changes in the coefficients. Most importantly, they confirm the main conclusion that an acceleration in population growth, even concentrated in the 15-64 group, reduces GDP per capita at impact sufficiently that the short-term impact on total GDP is not significant. Again, this is associated to a reduction in hours worked per capita, mainly due to a fall in the employment rate. The positive effect of population growth on real house prices, gross fixed capital formation and residential investment are also maintained. The only conclusion that changes slightly concerns the long-term elasticity of residential and non-residential properties, whose long-term response to a 15-64 population shock approaches unity (1.04 and 0.88 respectively), consistent with the hypothesis that the dilution effect disappears in the long run for these capital components.

As a final robustness check, an additional estimation was carried out to see if the exceptional macroeconomic movements prevailing during the COVID-19 pandemic have acted as outliers. For this reason, the equations were estimated over the 1981-2019 period. The results, not presented in the paper but available upon request, confirm that the main conclusions presented in this paper do not arise from observations for the years 2020 and 2021.

CONCLUSION

In the last forty years, faster population growth in Canadian provinces was accompanied by a substantial and significant reduction in real GDP per capita, mainly because of a decline in the proportion of the population employed and, to a lesser extent, to a lower labour productivity. This impact has been largely concealed by the endogenous response of people towards regions providing better employment and income opportunities. At the same time, population growth led to an increase in housing prices and an acceleration of investment which was shifted away from infrastructure and equipment towards the construction of buildings, and particularly residential ones. Although buildings have a long run response commensurate to population growth, particularly if population growth is concentrated in the working age group, a growing shortfall in infrastructure and of machinery and equipment seem inevitable given the absence of a statistically significant response to population growth even in the short term.

No statistically significant effect of population growth on wages or to the return on capital is detected, showing that inducing the macroeconomic effect of population shocks from their impact on factor compensation can be misleading. On the other hands, the negative impact on the employment to population ratio is consistent with the fact that increasing demographic growth through immigration may, as the federal government claim, helps to alleviate labour shortages in the short-term, at the cost of a reduction in living standards and a more difficult access to housing.

The main conclusion of the paper is that, in view of the tiny response of total GDP to population growth, and the incapacity of infrastructure and machinery to follow the growth in population, the dual objectives of immigration policy, promoting economic growth and responding to the short-term labour needs, seem hard to reconcile if the long-term goal is understood as an improvement in the standard of living and not solely accelerating total GDP growth. Yet, as the methodology focuses more on the short-term effect, conclusions regarding the long-term impacts on the well-being of Canadians must be taken with caution. It remains possible that the standard of living could be boosted in the future if demographic dynamism stimulates the pace of innovation, contributes to a substantial increase in the proportion of working-age people, increases the average quality of human capital, or if a larger domestic market enables economies of scale. It seems imperative to document the conditions that would allow these gains to unfold at the national level, areas in which further studies are needed.

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APPENDIX 1: DATA SOURCES

The price of housing is the 12-months average of the MLS monthly transaction prices of the Canadian Real Estate Association. Il was converted to real value by dividing by the annual average of the provincial consumer price index taken in Table 18-10-0004-01 of Statistics Canada.

Hourly productivity is real GDP divided by the number of hours worked during the year. GDP data come from Table 36-10-0222-01, while the hours were extracted from Table 14-10-0042-01. The latter gives estimated hours worked during the reference week. Summing the values gives the total for 12 weeks, which is multiplied by 4.3 to estimate the annual hours worked over 52 weeks.

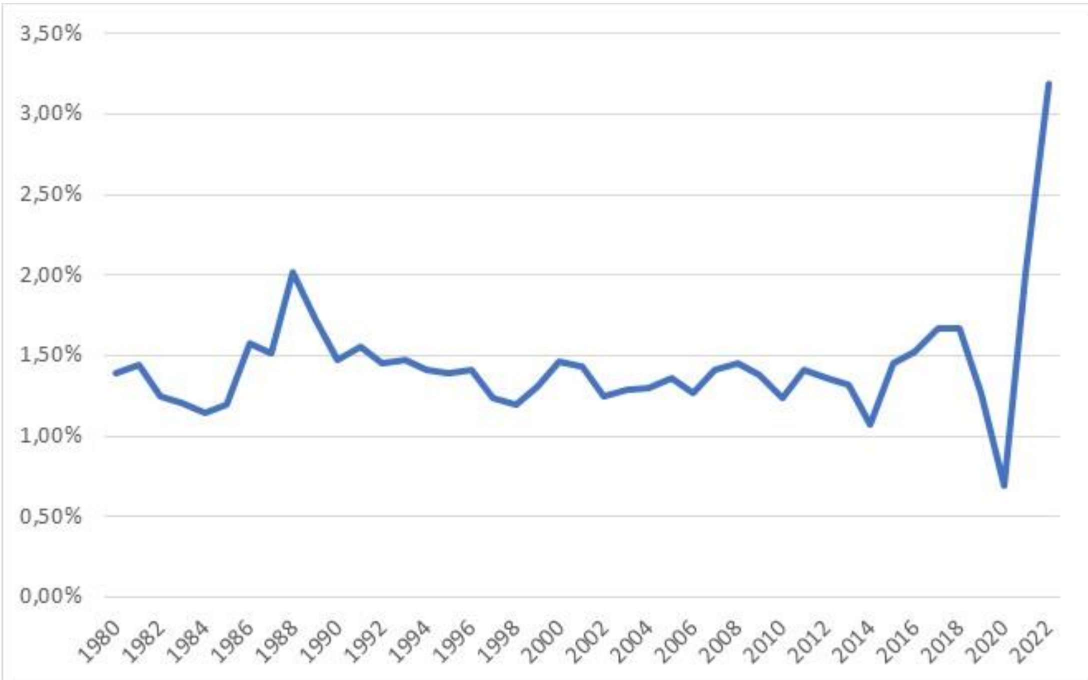
Population is calculated from quarterly data in Table 17-10-0009-01. The annual growth rate for year *t* is the population growth rate between the 1st quarter of year *t* and the 1st quarter of year *t*+1. As to real GDP per capita, it is obtained by dividing real GDP by the average population for the 4 quarters of the same year.

Data on employment and population aged 15 to 64 are taken from monthly data in table 14-10-0287-01. The number of jobs is the average for the 12 months of the year, while employment growth is that measured from January of the current year to January of the following year.

Data on non-residential capital are extracted from Table 36-10-0096-01 while those on residential capital are taken from Table 36-10-0099-01.

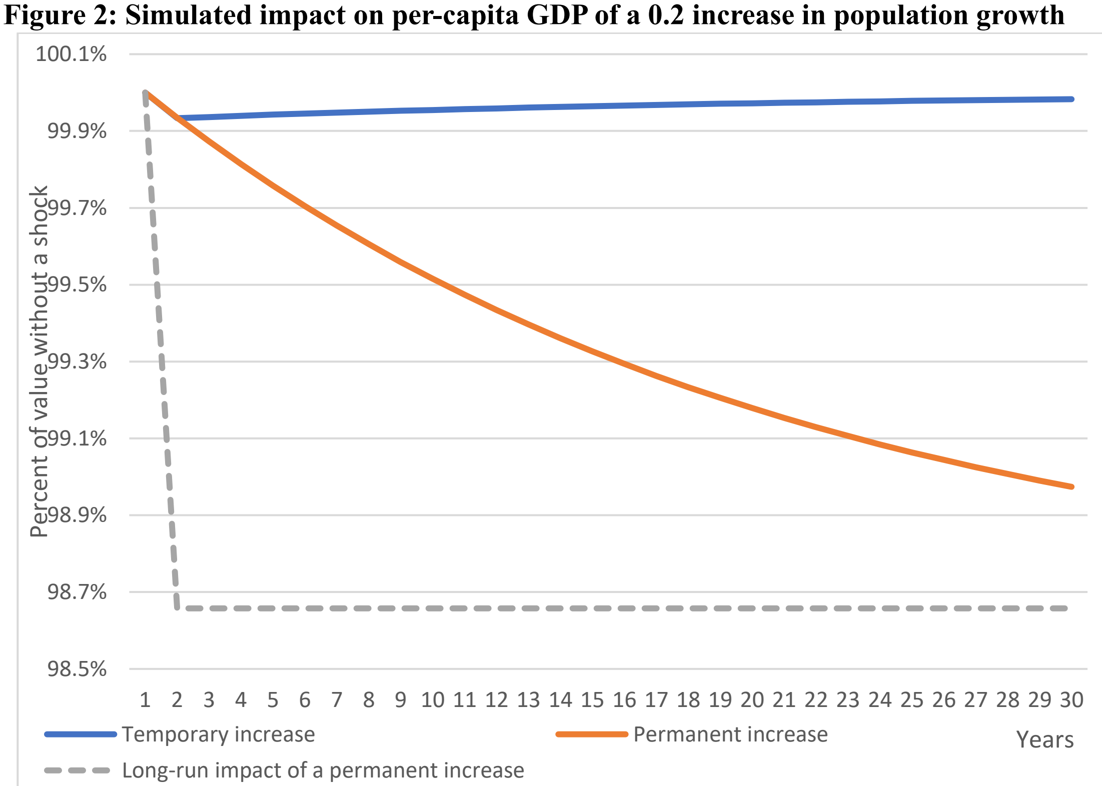
APPENDIX 2: FIGURES

Figure 1: Canada's population growth rate



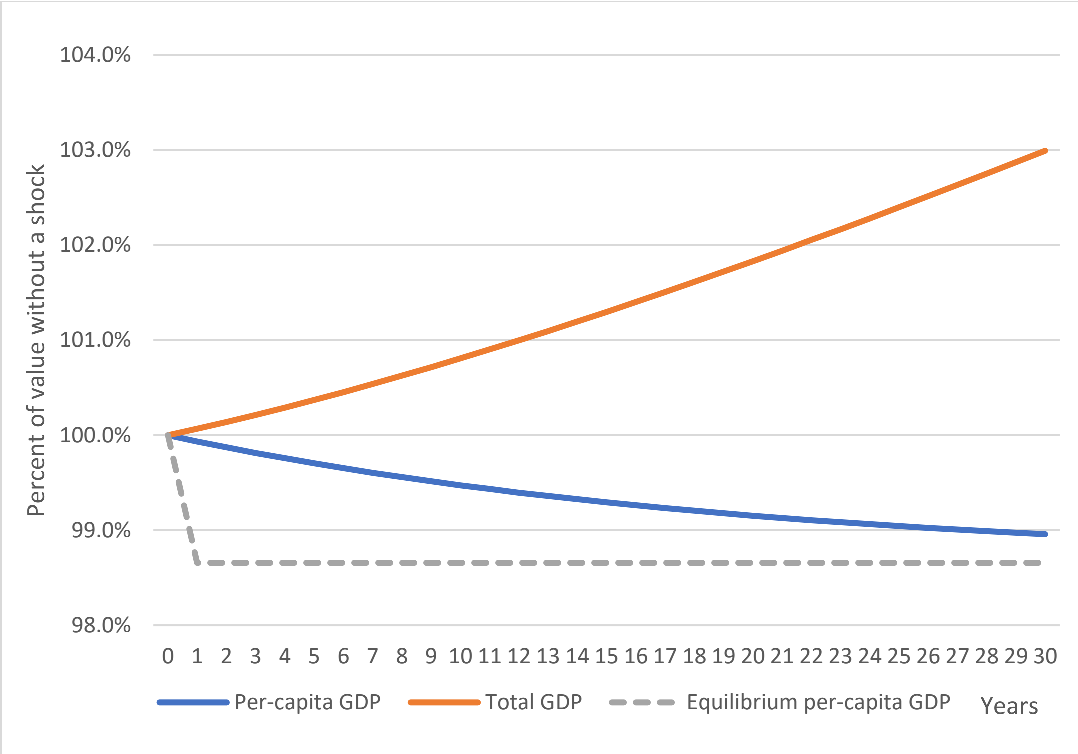
Source: Statistics Canada, Table 17-10-0008-01

Figure 2: Simulated impact on per-capita GDP of a 0.2 increase in population growth



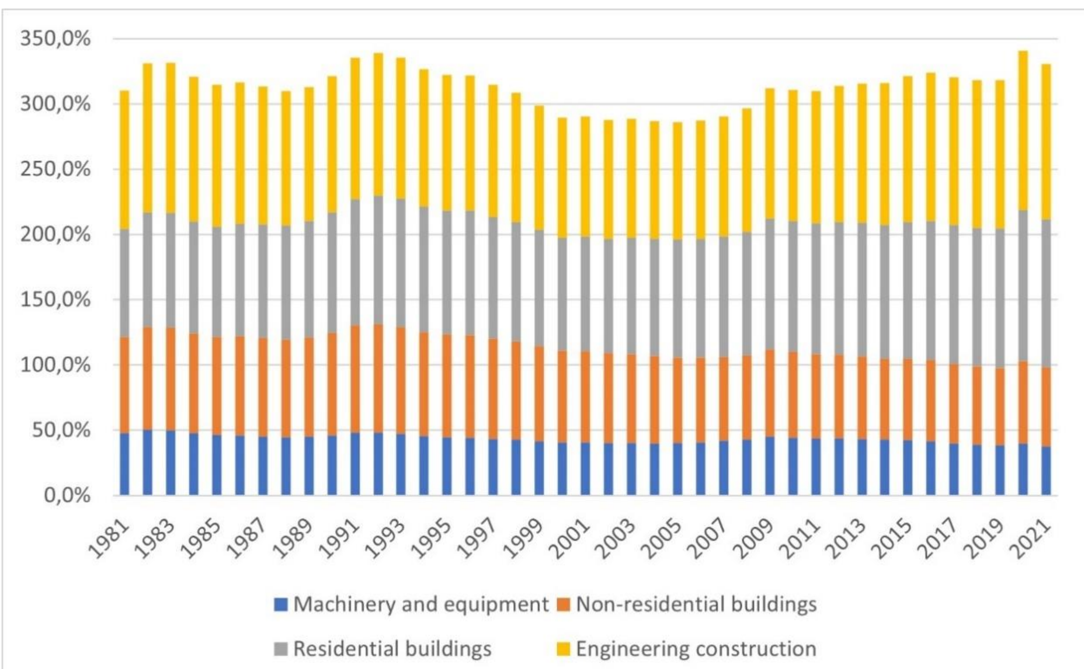
Source: Author's calculation.

Figure 3: Simulated impact on total and per-capita GDP of a 0.2% permanent increase in population growth.



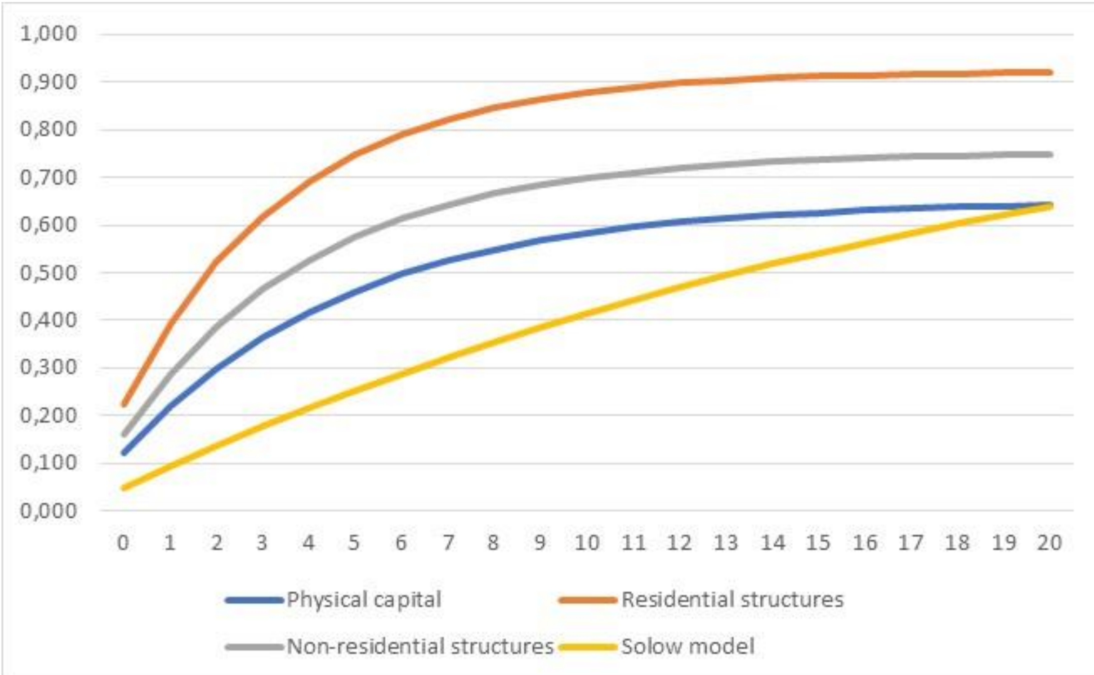
Source: Author's calculation.

Figure 4: Physical capital as a percentage of GDP



Source: Statistics Canada, tables 36-10-0096-01, 36-10-0099-01, 36-10-0222-01 and author's calculation.

Figure 5: Response in % of different types of physical capital to a 1% increase in population



Appendix 3: Results with the 15-64 age group (Two-stages least squares)

Macroeconomic performance				
Variable	**Per-capita GDP**	**Labour productivity**	**Per-capita hours**	**Per-capita employment**
C	0.015*** (0.006)	0.012*** (0.003)	0.003 (0.006)	0.003 (0.004)
$P1564G_t$	-0.964** (0.319)	-0.595** (0.267)	-0.736*** (0.263)	-0.534*** (0.142)
KG_{t-1}	-0.063 (0.128)	0.184* (0.104)	-0.116 (0.127)	-0.005 (0.071)
$YIELD_{t-1}$	0.518*** (0.178)	-0.050 (0.111)	0.530*** (0.182)	0.336** (0.127)
$TRADE_t$	0.005 (0.033)	-0.049 (0.029)	0.073*** (0.019)	0.023* (0.012)
Weighted R^2	0.056	0.038†	0.045	0.029

Factors income				
Variable	**Labour Income (CPI)**	**Labour Income (GDP deflator)**	**Rate of return on capital**	**Real housing price**
C	0.006 (0.004)	0.009** (0.004)	0.004*** (0.001)	0.009 (0.010)
$P1564G_t$	0.049 (0.252)	-0.082 (0.263)	0.130 (0.103)	2.144*** (0.503)
KG_{t-1}	0.253*** (0.102)	0.313** (0.126)	-0.246*** (0.043)	-0.547*** (0.195)
$YIELD_{t-1}$	-0.155 (0.140)	-0.249* (0.139)	0.080** (0.038)	0.850 (0.518)
$TRADE_t$	-0.016 (0.018)	-0.525*** (0.023)	0.143*** (0.011)	0.122*** (0.044)
Weighted R^2	0.048†	0.598	0.570	0.198

Final demand as shares of GDP

Variable	Consumption	GFCF	Residential structures	Non-residential structures	Machinery & equipment	Net exports
C	0.074*** (0.026)	0.052*** (0.009)	0.006** (0.002)	0.010*** (0.002)	0.019*** (0.002)	-0.006 (0.004)
$P1564G_t$	0.134 (0.204)	0.453*** (0.210)	0.187*** (0.047)	-0.021 (0.107)	0.051 (0.057)	-0.629** (0.304)
KG_{t-1}	0.022 (0.101)	0.196 (0.128)	-0.096*** (0.019)	0.293*** (0.062)	-0.002 (0.028)	0.305* (0.171)
$YIELD_{t-1}$	-0.245*** (0.048)	0.163 (0.050)	0.033 (0.032)	-0.014 (0.024)	0.084** (0.038)	-0.212* (0.118)
$TRADE_t$	-0.361*** (0.017)	-0.040** (0.015)	-0.015*** (0.003)	-0.021** (0.010)	-0.005 (0.005)	0.394*** (0.022)
LAG of dep	0.912*** (0.028)	0.695*** (0.051)	0.880*** (0.041)	0.648*** (0.048)	0.660*** (0.041)	0.874*** (0.024)
TIME	0.015* (0.008)	0.024*** (0.007)	0.011** (0.004)	0.012*** (0.003)	-0.018*** (0.003)	-0.011 (0.011)
Weighted R^2	0.985	0.833	0.886	0.856	0.761	0.971

Growth rate of capital					
Variable	**Physical capital**	**Residential buildings**	**Non-residential buildings**	**Machinery & equipment**	**Engineering structures**
C	0.002** (0.001)	0.004*** (0.001)	0.003*** (0.001)	-0.001 (0.001)	0.003** (0.001)
$P1564G_t$	0.156* (0.075)	0.276*** (0.081)	0.191*** (0.048)	-0.138 (0.133)	0.105 (0.117)
LAG of dep	0.810*** (0.032)	0.734*** (0.039)	0.784*** (0.032)	0.872*** (0.031)	0.750*** (0.039)
$YIELD_{t-1}$	0.059*** (0.016)	0.071 (0.046)	0.003 (0.032)	0.200*** (0.069)	0.084*** (0.026)
$TRADE_t$	0.019*** (0.006)	0.011** (0.004)	0.014 (0.010)	0.062*** (0.016)	-0.005 (0.008)
Weighted R2	0.836	0.808	0.769	0.752	0.683

Each equation is estimated with fixed cross section effect, the SUR option selected for cross-section correlated disturbance and the White cross-section correction for heteroscedasticity. Standard errors are between brackets. Coefficient significances are marked at the 10 %, (*), 5 % (**) and 1 % (***) level.