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POPULATION GROWTH AND THE DYNAMICS OF CANADIAN DEVELOPMENT: A MULTIVARIATE TIME SERIES APPROACH

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I. Introduction

Some years ago Chambers and Gordon (1966), using a general equilibrium model set within a counterfactual context, ignited a controversy over the contribution of exports to the growth in per capita income in Canada during the first decade of this century. The results, which implied that the contribution of trade to welfare gains was relatively small, had wider implications than those for an understanding of Canadian economic growth during this period. They called into question much of the literature in development economics that encouraged the export of natural products as a way of raising the standard of living in less developed countries. Chambers and Gordon used the increase in prairie rents between 1900 and 1910 as the measure of welfare gain. On this basis they concluded that the contribution of the wheat boom to the 23% growth in per capita income during this decade was only 1.94% (or only 8.4% of actual growth). The major share of intensive growth was therefore due to factors not related to wheat exports but rather was accounted for by the growth of technology. Much of the critical work that followed the publication of their piece was concerned with expanding the size of the contribution of exports to growth beyond the single index of rent on western farm land.[1] Recent developments in time series analysis, coupled with the publication of new long-run GNP estimates (Urquhart, 1993), allows us to revisit this controversy, although from a very different perspective than that adopted by Chambers and Gordon, or their critics.

At the heart of the Canadian debate was whether the rapid settlement of western Canada after the turn of the century caused a structural break in long-run development. Earlier national accounts estimates (Firestone, 1958) suggested that the increase of growth in per capita income after 1900 was quite small compared to that observed in the previous three decades - a period generally described by traditional economic historians as one of desultory growth. The Chambers and Gordon results

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[1] Examples of this can be found in Caves (1965), Bertram (1973) and Lewis (1981).

seemed to confirm these findings. This basic perception changed dramatically with the publication of the Urquhart (1993) series. The latter, unlike those recorded by Firestone, showed a sharp break in the growth of GNP per capita around the turn of the century. These new estimates align closely with the traditional explanation of the impact western settlement exerted on the long-run development of the Canadian economy. Mackintosh (1967), the best exponent of the traditional school, saw the settling of the West and the subsequent export of wheat, as a major dynamic force that shaped Canadian growth in the early decades of this century.

What follows is an attempt to apply time series analysis to the impact of trade on growth. The approach is to specify a simple dynamic model of Canadian development and estimate it using the new annual national accounts series for the period 1870 to 1930. Section II sets out the model and Section III reviews the evidence for structural breaks. Section IV describes our empirical results and conclusions are presented in Section V. The most striking result is the substantial contribution coming from innovations in population. It appears that this reflects the vigorous recruitment of immigrants in the early years of the century. Our analysis suggests that this policy shifted up the growth path of per capita income by 5.7%.

II. Trade and Economic Growth

The variables tested are derived from a model developed by Caves (1965). In an attempt to formalize the effect of trade on growth, Caves divided the process into two segments. The more stable part, he argues, is defined by a simple neo-classical growth model. Here income growth is driven by "a gradual increase in population, capital stock, and the general level of labour proficiency and technical knowledge as they affect productivity in all production processes". (Caves, 1965, p. 102). Export-based growth, the less stable part, explains a large fraction of the variation in observed income growth. The empirical question of how much of the average rate of total growth is explained by exports is not answered in his presentation.

We find Caves approach particularly interesting since it formally recognizes the cyclical aspects of long term growth, and ties the latter to dynamic periods of expansion (and contraction) associated with resource exploitation. In addition, this view of the growth process suggests that difference stationarity, rather than trend stationarity, representations of the resulting time series may be more appropriate.[2] This results from the fact that export booms increase the flow of immigration and so lead to a permanent increase in the population.

Although our model is grounded in traditional neoclassical growth theory, it is not inconsistent with newer approaches that emphasize endogenous innovation.[3] In particular, we do not express the variables in per capita terms but rather include population as a separate variable. This allows an increase in population to generate an increase in per capita income through, for example, induced innovation related to increased market size.

In the empirical analysis below, we focus on the variables suggested by the Caves approach, namely, GNP, investment, exports, population and the terms of trade.

III. The Evidence for Structural Breaks

An early attempt to search for breaks in long run trends in industry growth was undertaken by Bertram (1963). He came to the following conclusion (p. 171):

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[2] Difference stationarity means that the level of the time series (but not the first difference) exhibits a unit root so that disturbances will have permanent effects. If it follows a deterministic trend and has no unit root, it is said to be trend stationary. The basic reference on unit roots in economic time series is Nelson and Plosser (1982).

[3] For a discussion of endogenous growth in the context of empirical analysis of long-run growth, see Crafts (1995).

> The manufacturing series, within its limitations, appears to cast serious doubt in Rostow's dating of a take-off in Canada and, in addition, suggests that the analogy of a take-off is not an appropriate tool of analysis for Canadian growth experience.

In reaching these conclusions Bertram used the conventional method of trend analysis, i.e., he applied OLS estimation to a deterministic trend relationship, $y = \alpha + \mu t$. Bertram partitioned his 87 year period into 15 different sub-periods of varying length. The choice of sub-period was partly dictated by the availability of census reports for the years prior to 1911. Thereafter, when more frequent estimates became available, he was able to choose sub-periods by business cycle turning points, war etc. We have, in his paper, a classic example of the analysis of a single time series stretching over a long period of time.[4]

Two recent studies have examined the hypothesis of a structural break in Canadian growth between the last third of the 19th Century and the opening years of this century. Inwood and Stengos (1991, p. 280), found that:

> ... the wheat boom and both Wars changed the growth process in the sense of altering the underlying trend by which GNP and investment expanded.

This conclusion is based on the finding that GNP exhibits a unit root over the whole period while stationary processes are found within each sub-period when three structural breaks are taken into account.

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[4] A recent attempt to search for structural breaks in long-run time series, using more formal methods of time series analysis, can be found in Crafts et. al. (1990). In examining industrial output for eight European countries during the 19th century, the authors find difference stationary processes in all but one case.

An important element in this debate over the impact of western settlement was the question of the timing of the process. The American west had begun to fill up rapidly after the end of the Civil War, while large scale settlement of the Canadian west did not begin until the late 1890's. Moazzami, Norrie and Percy (1988), focused on this question in their paper. They tested a simple model of the settlement process by relating homestead entries to the price of wheat and the stock of railway mileage. They used the Engle-Granger (1987) cointegration procedure and concluded that (p. 23):

> ... railroad mileage and wheat prices were significant determinants of the extensive margin and that evidence exists of a structural break in this equilibrium process at the turn of the 20th Century

In general, then, it appears that we have not progressed far in our overall understanding of the settlement process since Mackintosh's earlier views were stated. The variables suggested by the work of Mackintosh and Caves still seem important but we are not much closer to an understanding of their relative influence. The model presented in the next section of this paper focuses on this question.

IV. Empirical Results

Our review of the literature suggests two approaches to the characterisation of the growth process. One, exemplified by Crafts et. al. (1990), estimates a single time series model for the entire sample period and uses it to explain variations in growth rates over time. The other, exemplified by Inwood and Stengos (1991), focuses on the exogenous structural breaks. In this paper, we follow the former approach and apply the Engle-Granger (1987) cointegration procedure to the time series data on the logarithms of real GNP, real investment, real exports, population, and the terms of trade over the period 1870 to 1939. The objective of the analysis is to construct an empirical model of the growth process that allows for dynamic interactions of the variables through the use of a vector autoregressive system. We then view the apparent discontinuities in the time path of GNP as reflecting the changing relative importance of different innovations. In particular, we use the model to analyse the contributions of exports, investment and population growth during the wheat boom years of 1896 to 1913.

Unit Root Tests

The first stage is to determine the order of integration of the time series by testing for unit roots using Dickey-Fuller (1979) tests. In Table 1, we show the t-statistic for the Dickey-Fuller tests based on the following regressions:

Dickey-Fuller (DF) test:

(a) $$\Delta y(t) = \alpha + \beta y(t-1)$$

(b) $$\Delta^2 y(t) = \alpha + \beta\Delta y(t-1)$$

Augmented Dickey-Fuller (ADF) test:

(c) $$\Delta y(t) = \alpha + \beta y(t-1) + \delta\Delta y(t-1) + \mu t$$

(d) $$\Delta^3 y(t) = \alpha + \beta\Delta^2 y(t-1)$$

Regressions (a) and (c) test for stationarity in the levels while (b) and (d) test for integration of order one [I(1) or difference stationarity]. Under the Engle-Granger procedure, we must first establish that the series are I(1).

The tests indicate that, using the MacKinnon (1991) critical values, we cannot reject the null hypothesis of a unit root. However, when these series are differenced, the hypothesis of a unit root is rejected. In the case of the population variable, the results are somewhat weaker in that the t-test is significant at the 5% but not at the 1% level. The same result is obtained using the augmented test for exports and the terms of trade.

Test of Co-integration

The second stage of the Engle-Granger procedure is to test for cointegrating relationships which can be interpreted as the long-run equilibrium relationships among the variables. Such relationships exist if the variables are cointegrated, that is, if there exists one or more linear combinations of these (nonstationary) variables which is stationary. The results obtained using the Johansen (1991) test are shown in Table 2.[5] The likelihood ratio test rejects, at the 1% level, the null hypotheses of no or at most one cointegrating equations so that we can conclude that there are two such relationships.

Error Correction Model

The last stage of the analysis is to estimate a vector error-correction model of the short run adjustment process. The change in each variable is regressed on the lagged errors from the two cointegrating regressions and the lagged changes in all of the variables. The error term represents the deviation from equilibrium while the other variables capture the dynamics. The Johansen method allows us to estimate a vector autoregression (VAR) that is consistent with the steady state relationships implied by the cointegrating relationships.

Figures 1a and 1b show a selection of the impulse-response functions using orthogonalized innovations based on the following ordering:

LPOP	Population
LT	Terms of Trade
LX	Exports
LINV	Investment
LY	GNP

[5] We assume a deterministic trend in the data, and a constant but no trend in the cointegrating equations. Two lagged terms are included.

This means that GNP is affected by contemporaneous innovations in all variables, investment is affected by all except GNP, etc. The first variable in the list, population, is assumed to be entirely exogenous in the sense that it is not affected by contemporaneous innovations in any of the other variables.

Focusing on the interaction between population and GNP, we see from Figure 1a that a population innovation builds up to a maximum effect on population itself in about eight years. Income and exports show a substantial and lasting response while, as would be expected from a neoclassical growth model, the effect on investment is much larger in the short run than in the long run. These effects can be identified as arising from changes in Canadian immigration policy or push factors that induce immigration through changes in conditions in the source countries. Economic pull factors that attract immigration to Canada are illustrated in the response of population to an income innovation shown in Figure 1b. Again the effect builds up to a maximum in about eight years.

Since population innovations play an important role in the simulations reported below, we examined the sensitivity of the impulse-response functions to the ordering of the variables. In particular, we recalculated the responses shown in Figure 1a putting population at the bottom of the list so that only the part of this variable that is uncorrelated with all the others is included in the population innovation. By comparing Figures 1a and 1c, we see that this reordering has little effect except in the case of the terms of trade (LT) where the response is quite small.[6]

Simulations

These impulse-response functions are a convenient way of comparing the effects of innovations in each of the variables by tracing the effect of a one standard deviation

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[6] As a result of the reordering, the first period responses of the other four variables to a population innovation are no longer constrained to zero as they are in Figure 1a.

shock. They can also be used to decompose the actual path of a variable over a particular time period into the effect of the initial conditions and the effects of the various estimated innovations. Figure 2 shows the results from using our model to simulate the wheat boom period, 1896 to 1913. F0 shows the time path of GNP that would have been traced out between 1896 and 1929 in the absence of any innovations, and is generated by the dynamics of the model given the initial conditions, that is, the values of the variables in 1894 and 1895. F1 shows the effect of including the innovations in exports over the period 1896 to 1913, F2 shows the effect of adding investment, and F3 shows the effect of adding innovations in population. F4 includes all innovations and is equal to actual GNP from 1895 to 1913. Zero innovations are assumed after 1913 and the growth paths of all the series flatten out by the mid-twenties. The lower panel shows the same data in the form of the noncumulative individual effects of each innovation and the effect of all innovations. The steady state effects on income, as approximated by the effects in 1929, are shown in the first column of Table 3.

As can be seen from Figure 2, exports were the major source of stimulus from 1896 to 1908 while investment is also important after 1909. More striking in this latter period is the substantial contribution coming from innovations in population. From examining the estimated innovations, it is clear that this reflects the lagged effect of a major spike in immigration in 1907. Turning to the first column of Table 3, we see that as a result of all shocks, the growth path of income shifted up by 35.5%. Exports (19.5%) and population (16.5%) exerted the primary lasting effects on income.

Figure 3 and the second column of Table 3 show the effects on investment. As represented by the steady state effects, investment innovations again play a small role but there is a 35.4% increase in investment as the innovations in the other variables work through the dynamics of the model. In contrast, we see from Figure 4 and the last column of Table 3, that 70% (10.8/.153) of the increase in population resulted from its own innovations. This implies a predominance of immigration policy and/or push factors over pull factors in determining immigration during the wheat boom period. In fact, a review of the data for the period reveals a jump in immigration in the middle of the first decade of this century from both Britain and the continent. It appears that this reflects a policy vigorous recruitment of immigrants.

V. Conclusions

In this paper, we estimate a vector autoregressive model of the growth process in Canada that allows for dynamic interactions among GNP, investment, exports, population, and the terms of trade over the period 1870 to 1939. We then account for the apparent discontinuities in the time path of GNP by simulations that indicate the changing relative importance of different innovations. In particular, we use the model to analyse the contributions of exports, investment and population growth during the wheat boom years of 1896 to 1913.

The most striking result is the substantial contribution coming from innovations in population. It appears that this reflects vigorous recruitment of immigrants in the early years of this century. Our analysis suggests that this policy shifted up the growth paths of income, population and per capita income by 16.5%, 10.8% and 5.7% respectively.

When all innovations are taken into account, the shifts in the growth paths are 35.5%, 15.3% and 20.2% respectively. In line with the traditional view of Mackintosh, almost all of the remainder of the stimulus to income derives from exports. Innovations in investment play a small role but there is a substantial endogenous investment boom as the innovations in the other variables work through the dynamics of the model. Thus our results do not contradict the observation of Urquhart (1986, p. 35-36) that:

> ... the Canadian economy developed in a fundamentally different way after 1900 than it had before. The best evidence in support of this

statement from our data is provided by the performance of capital formation

It is worth noting that our effects on per capita income are very much larger than the 1.94% reported by Chambers and Gordon, although they are clearly not fully comparable. In addition to the fact that we focus on a wider range of factors operating during the wheat boom period, we are using a dynamic model. Theirs is a static model that requires assumptions about the system being in equilibrium both in 1900 and, even more doubtfully, in 1910. Further, they yield no ground on the enhancement of productivity resulting from large scale settlement. On the contrary, the production function for "gadgets" is "linear and homogeneous which implies no external technological economies or diseconomies" (Chambers and Gordon, 1966, p. 324). They do not believe, as have earlier writers, "that, by increasing income and population initially, exports may increase demand so that a secondary improvement in productivity results from economies of scale" (p. 326). They eliminate economies of scale mainly by assertion and by reference to studies of growth in the United States, not by evidence for the Canadian case. In contrast, our analysis highlights the importance of both population and exports as sources of stimulus and clearly shows that there are economies of scale that generate increased per capita income.

Table 1: Unit Root Tests 1870-1939					
	GNP	Investment	Exports	Population	Terms of Trade
DF Test					
Level	0.56	1.28	0.21	0.42	2.12
First Difference	6.55**	5.36**	5.39**	3.48*	10.26**
Augmented DF Tests (one lag term and trend in level tests)					
Level	2.40	2.67	3.18	1.85	2.75
First difference	4.86**	4.89**	5.66*	2.97*	6.00*

* significant at the 5% level
** significant at the 1% level

Table 2: Johansen Cointegration Test 1870-1939				
	Likelihood	Critical Values		Hypothesised
Eigenvalue	Ratio	5%	1%	No. of CE(s)
0.475	98.8	68.5	76.1	None**
0.358	55.6	47.2	54.5	At most 1**
0.242	25.9	29.7	35.7	At most 2

Test assumes a deterministic trend in the data, and a constant but no trend in the cointegrating equations.

Table 3: Simulated Steady State Effects			
Innovation in	Steady State Effects on:		
	GNP	Investment	Population
Investment	0.013	0.004	0.016
Exports	0.195	0.252	0.007
Population	0.165	0.133	0.108
Other	-0.018	-0.035	0.022
Total	0.355	0.354	0.153

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