Journal of International Economics 44 (1998) 257–287

The international transmission of economic fluctuations: Effects of U.S. business cycles on the Canadian economy

Stephanie Schmitt–Grohé*

Board of Governors of the Federal Reserve System, Washington, DC 20551, USA

Accepted 28 April 1997

Abstract

This paper suggests that for a wide class of international real-business-cycle models, including models with imperfect competition, the traditional channels of international transmission of business cycles through world-interest-rate and terms-of-trade variations cannot explain the cyclical response of the Canadian economy to innovations in U.S. output. Empirically testable quantitative models of the effects on Canadian economic activity of shocks to the U.S. economy are developed and their empirical relevance is tested by comparing impulse responses estimated from vector autoregressions to the quantitative predictions of the theoretical models. © 1998 Elsevier Science B.V.

Keywords: International transmission of business cycles

JEL classification: E30; F40

1. Introduction

Can trade alone explain the cross-country comovements of macroeconomic aggregates at business-cycle frequencies? This paper suggests that for a wide class of international real business-cycle models, including models with imperfect competition, the answer is no. The paper examines whether international trade in goods and financial markets can account for the observed effects of U.S. business

*Tel.: +1 202 452 2907; fax +1 202 452 2301; e-mail: sgrohe@frb.gov

PII S0022-1996(97)00031-7

cycles on the Canadian economy in a setting in which trade transmits cyclical fluctuations through its effects on world interest rates and relative prices.

Cross-country business-cycle correlations have been widely documented, and empirical studies consistently find that cyclical variations in output and other macroeconomic aggregates are positively correlated across countries. Attempts to explain these correlations in a dynamic equilibrium-business-cycle framework have been made by a number of recent authors (for example, Backus et al., 1992; Stockman and Tesar, 1995).[1] In most of this literature, however, the only implications of the theoretical models that are examined are the implied correlation and relative volatility properties of macroeconomic time series when the model economy is subjected to technology or taste disturbances. Such analyses test a complex joint hypothesis, involving specification of both the transmission mechanism and the set of exogenous shocks generating short-term fluctuations in different countries. This paper, in contrast, tries to isolate the importance of the transmission mechanism and asks whether it alone can explain the effects of foreign business cycles on the home economy. Transmission mechanism here means the propagation of shocks in a foreign economy to domestic endogenous variables through international trade in goods and financial markets and through effects on world relative prices.

In the case of any given equilibrium model, one can ask how a shock affecting output in a foreign country affects equilibrium in the home country. This implication of the model can furthermore be tested assuming that one is able to identify shocks of the particular type being considered. An empirical strategy of this kind has the appealing feature that one does not have to specify the complete set of shocks that generate short-term fluctuations—not even the complete set of shocks affecting the home economy. By contrast, the set of predictions tested in the literature just cited depends upon specification of the complete set of shocks affecting both countries.

If both countries under consideration are large, then a shock that directly affects output in the foreign economy may be hard to identify because it might be caused by economic conditions in the home country. However, for a small-large country pair, a shock in the large economy can be identified because one has little reason to believe that such a shock represents responses to the small country's economic conditions. This identification problem suggests to consider small–large country pairs in which the large country is an important trading partner of the small country. The Canadian and U.S. economies accordingly form a suitable small–large country pair. Furthermore, many authors have discussed the effects on Canadian economic activity of changes in U.S. output, and U.S. business cycles have often been assigned an important role in the generation of aggregate fluctuations in Canada in the recent decades (see, for example, Burbidge and

[1] For a survey of this literature see Backus et al. (1994).

Harrison, 1985; Ambler, 1989; Johnson and Schembri, 1990). The empirical analysis therefore focuses on the transmission of U.S. fluctuations to the Canadian economy.

Impulse responses estimated in this paper show that Canadian output, employment, investment, exports, imports, and terms of trade (measured as the ratio of export to import prices) respond positively to a positive innovation in U.S. gross national product (GNP). The paper analyzes the ability of three transmission channels to explain these observed responses: (1) Financial markets: shocks to the U.S. economy affect the Canadian economy through changes in the rate of return on international financial assets available to Canadian agents; (2) Export markets: shocks to the U.S. economy affect Canadian activity through changes in the terms of trade in response to variations in export demand; (3) Imperfectly competitive export markets: shocks to the U.S. economy affect the Canadian economy through changes in export demand and in market power of imperfectly competitive export producers.

The financial market transmission channel represents the simplest hypothesis, as it is consistent with the assumptions of a single internationally traded good and perfect competition (though it requires neither). I thus consider this channel first in the context of a competitive one-sector model, an analytical framework that has been extensively used to explain various international business-cycle regularities.[2] In the one-sector model, changes in investment opportunities in the foreign economy, which may include a revaluation of the agents' international portfolios, are the only potential explanation for the international transmission of business cycles besides correlation of the underlying shocks. The computed model impulse responses show that this channel fails to match the estimated responses of output, investment, and employment simultaneously.

To analyze whether business cycles are transmitted through variations in export demand, the one-sector framework is extended to include two goods, one produced exclusively in Canada (Canada's export good) and one supplied elastically to Canada on a world market (Canada's import good). The paper shows that transmission through export-demand variations accounts better for the behavior of output and hours than transmission through financial markets; however, the quantitative predictions for output and hours are still weaker than the estimated ones.

In the two-good competitive-equilibrium model, variations in export demand affect equilibrium in the Canadian economy only through their effects on the terms of trade. If one assumes that exporters have market power and that the market structure is like that in the implicit collusion model of Rotemberg and Woodford (1992), then variations in export demand affect the domestic economy through terms-of-trade and also through markup changes. This transmission channel can

[2] See Backus et al. (1992); Baxter and Crucini (1993); Cantor and Mark (1988); Cardia (1991); Finn (1990); Kollmann (1990), (1993); Mendoza (1991).

quantitatively explain the observed responses of investment, output, and hours, but it still fails to explain the behavior of exports and the terms of trade. Therefore the basic conclusion of the paper is unaffected by the introduction of imperfect competition and implicit collusion among exporters: In international real business-cycle models, the traditional channels of transmission, namely price variations (that is, interest rate and terms-of-trade variations), fail to explain the cyclical response of the Canadian economy to innovations in U.S. output.

The remainder of the paper is organized in four sections. Section 2 develops the baseline one-sector, small-open-economy model. Section 3 describes the procedure for testing the empirical relevance of the various transmission channels by applying it to the interest rate channel. Section 3 first presents the estimation of the impulse responses of Canadian macroeconomic aggregates to an innovation in U.S. output. Second, it describes the calibration of the model and the computation of the predicted impulse responses to an innovation in U.S. output. Third, it illustrates the way these two sets of impulse responses are used to test the success of the financial market or interest rate transmission channel. In Section 4, the basic model is extended and the hypothesis that transmission through export-demand variations, transmission through variations in export demand when exporters have market power, or transmission through both financial markets and export-demand variations can explain the observed effects of a U.S. output innovation on the Canadian economy is tested. Section 5 concludes the paper.

2. The basic model

A small-open economy produces and consumes one good. Its residents have access to a frictionless domestic as well as international capital market. Prices in the international asset market are exogenously determined. The economy consists of a large number of identical infinite-lived households. The representative household seeks to maximize

$$U(\{X_t\}_{t=0}^{\infty}) \equiv E_o\left\{\sum_{t=0}^{\infty} V(X_t)\exp\left[\sum_{\tau=0}^{t-1} -v\left(\frac{X_\tau}{z_\tau}\right)\right]\right\} \tag{1}$$

where the period utility function, $V(.)$, is assumed to be increasing, negative, and homogeneous of degree $1-\sigma$, $\sigma>1$ and the discount rate, $v(.)$, is assumed to be positive, increasing, and concave. X_t denotes a composite good which is homogeneous of degree one and increasing in C_t, the consumption by the household of the market good in period t, and in C_t^h, the consumption by the household in period t of a home-produced good, that is,

$$X_t = X(C_t, C_t^h) \tag{2}$$

The home good is produced during leisure time with the increasing and concave household production function

$$C_t^h = z_t f(l_t) \tag{3}$$

where l_t is leisure time of the household in period t. The process z_t represents exogenous labor-augmenting technical change, which is assumed to follow a deterministic trend ($z_{z+1} = \gamma_z z_t, \gamma_z > 1$). To make the discount rate stationary along a balanced growth path, I assume that z_t is also an argument of the discount rate $v(X_t/z_t)$.

This structure of preferences has two features that are not completely standard in the real business-cycle literature. First, it implies an endogenous discount factor, $\exp[-v(.)]$, which is decreasing in current consumption and leisure.[3] The endogenous discount factor guarantees the existence of a steady state that is (at least locally) unique as well as the existence of an equilibrium that involves stationary fluctuations around the steady state. The properties of such an equilibrium can easily be approximated using standard numerical methods. Second, leisure does not enter the period utility directly but is used to produce another good at home. Home production with technological progress is modeled here to allow for less-restrictive period utility functions in the presence of growth than would have to be assumed if the period utility were just a function of market-produced consumption and leisure.[4] The representative household's sequential budget constraint can be written as

$$C_t + w_t l_t + W_{t+1} \leq w_t \bar{H} + R_t^w W_t \tag{4}$$

where w_t is the wage rate in terms of the consumption good in period t, $\bar{H}$ is the household's endowment of hours, and W_t is the household's period t wealth in units of the consumption good. The stochastic process $\{R_t^w\}$ represents the payoff per unit of the portfolio in period t by the household. The household chooses sequences $\{C_t, C_t^h, l_t\}$ so as to maximize (1) subject to the sequence of budget constraints (2)–(4) and to some borrowing limit that prevents the household from engaging in Ponzi type schemes.

The condition for market clearing in the product market can be written as

$$Y_t = C_t + I_t + B_{t+1} - R_t B_t \tag{5}$$

where Y_t represents gross domestic product in period t, I_t is investment in period t, B_t is the amount of foreign assets held at the end of period $t-1$, and R_t is the

[3] This type of preferences has been introduced by Uzawa (1968), extended by Epstein (1983), (1987), and recently surveyed by Obstfeld (1990). It has been used by many authors; among them are Obstfeld (1981); Mendoza (1991); Uribe (1997).

[4] See also the discussion in the survey of Greenwood et al. (1994) on household production in real business-cycle theory.

exogenous process for the gross return on holding an internationally traded asset from period $t-1$ to period t. The evolution of capital is given by

$$K_{t+1} = (1-\delta)K_t + I_t - \varphi\left(\frac{K_{t+1}}{K_t}\right)K_t \tag{6}$$

where δ is the constant rate of depreciation of the capital stock, satisfying $0<\delta\leq 1$. Adjustment costs $(=\varphi(K_{t+1}/K_t)K_t)$ are introduced to smooth the reallocation of wealth between physical capital and the foreign asset in response to temporary-rate-of-return differentials. The function is assumed to be positive convex and is rigged in such a way that neither along a stationary growth path nor along small fluctuations around it are adjustment costs different from zero. Adjustment costs will influence only the investment decision along small fluctuations around the stationary growth path.

The aggregate production technology is given by

$$Y_t = F(K_t, z_t H_t) \tag{7}$$

where $H_t \equiv \bar{H} - l_t$ denotes hours supplied to the market by the household in period t. $F(.,.)$ is assumed to be Cobb–Douglas. Firms rent capital services and hire labor so as to maximize period profits. The labor demand then is related to the real wage by

$$F_H(K_t, z_t H_t) z_t = w_t \tag{8}$$

and the marginal product of capital is related to the rental rate of capital, u_t, as

$$F_K(K_t, z_t H_t) = u_t \tag{9}$$

As noted previously, households have access to frictionless domestic securities markets and the international bond market. From the optimal portfolio choice of the representative household one can price physical capital and international bonds. This implies the following two equations:

$$\begin{aligned}\left[1+\varphi'\left(\frac{K_{t+1}}{K_t}\right)\right]\lambda_t &= \exp\left[-\tau\left(\frac{X_t}{z_t}\right)\right] \\ &\quad \times E_t\left\{\lambda_{t+1}\left[u_{t+1} + 1 - \delta + \varphi'\left(\frac{K_{t+2}}{K_{t+1}}\right)\frac{K_{t+2}}{K_{t+1}} - \varphi\left(\frac{K_{t+2}}{K_{t+1}}\right)\right]\right\}\end{aligned} \tag{10}$$

and

$$\lambda_t = \exp\left[-v\left(\frac{X_t}{z_t}\right)\right]E_t[\lambda_{t+1}R_{t+1}] \tag{11}$$

where λ_t denotes the marginal utility of wealth in period t.

As z_t exhibits a positive trend output, the real wage, consumption, and the marginal utility of income will also have a trend. Under certain restrictions on the functions describing preferences and technology, the system of equilibrium conditions can be transformed into a system of stationary variables, and a steady state equilibrium can be shown to exist. The transformed stationary variables are $\tilde{Y}_t=(Y_t/z_t)$, $\tilde{C}_t=(C_t/z_t)$, $\tilde{X}_t=(X_t/z_t)$, $\tilde{\lambda}_t=\lambda_t z_t^{\sigma}$, $\tilde{K}_t=(K_t/z_t)$, $\tilde{B}_t=(B_t/z_t)$, $\tilde{w}_t=(w_t/z_t)$, and $\tilde{I}_t=(I_t/z_t)$. The restrictions are as follows. The composite X_t is assumed to be homogeneous of degree one in C_t and C_t^h. As the discount rate, $v(.)$, is assumed to be a strictly increasing function of the composite good, which itself is strictly increasing in both consumption goods, it will have a trend if consumption does. Along such an equilibrium path the discount factor would approach zero and a stationary equilibrium would not exist. To make the discount rate stationary along a balanced growth path, $v(.)$ is assumed to be a function of the stationary variable $\tilde{X}_t$. Under the assumption that $V(.)$ is homogeneous of some degree $1-\sigma$, $\sigma>1$, in steady state the present discounted value of expected future utility is well defined only if $\exp[v(\tilde{X})]\gamma_z^{\sigma}>\gamma_z$. From (11) we have $\exp[v(\tilde{X})]\gamma_z^{\sigma}=R$, so the inequality is satisfied only if $R>\gamma_z$.

For the period utility function used here, it is not required that the elasticity of substitution between consumption and leisure is one in order to reconcile the empirical fact that wage and consumption do have a trend whereas hours supplied to the market by the household do not, as is necessary when the period utility is a function only of consumption and leisure.[5] The household's objective function (1) can also be written in terms of the transformed variables. An equilibrium for the transformed economy then is a set of stochastic processes for the endogenous variables $\{\tilde{C}_t, H_t, \tilde{w}_t, \tilde{X}_t, \tilde{\lambda}_t, \tilde{K}_t, \tilde{B}_t, u_t, \tilde{I}_t, \tilde{Y}_t\}$ satisfying the first order conditions of the household's maximization problem and the transformed versions of Eqs. (5)–(11) given the exogenous process $\{R_t\}$. I approximate a solution to the set of equilibrium conditions by the solution to a log-linearization of the equilibrium conditions around the non-stochastic steady state, as in King et al. (1988).

3. Testing transmission through interest rate variations

In the model just presented, one can ask how a shock that directly affects output in the foreign country and is uncorrelated with any of the domestic shocks affects equilibrium in the home country. This implication of the model can furthermore be

[5] King et al. (1988) show that, for period utility functions of the form $V(c, \bar{H}-H)$, the only period utility function compatible with growth in consumption but no growth in hours is $\{V(c, \bar{H}-H)=c^{(1-\sigma)}g(\bar{H}-H)/(1-\sigma)$ for $\sigma\geq 0$, $\sigma\neq 1$ and $\log(c)+g(\bar{H}-H)$ for $\sigma=1$, which implies that labor supply by the household in period t (unless $\sigma=0$) always depends on the marginal utility of income. Under the specification adopted here, it is possible that time allocated to the market is stationary while both consumption and wage have a secular trend and that the (Frisch) elasticity of hours with respect to the marginal utility of income is zero, even if $\sigma>0$. In this case, wealth effects do not affect equilibrium in the labor market. This allows me to use the preference specification of Mendoza's (1991) nongrowing economy in my growing economy.

tested assuming that one can identify the particular type of shock being considered. In that case, one can estimate impulse responses of the macroeconomic variables of interest to this shock and evaluate the empirical validity of the model, or equivalently the transmission mechanism it implies, by comparing the estimated and predicted impulse responses. An appealing feature of this empirical strategy is that one can test a model's implied transmission mechanism without having to specify the complete set of shocks generating short-term economic fluctuations. For this strategy to be valid, it is enough that the shocks being modeled have effects that are independent of the effects of the shocks not being modeled. Such independence will in fact hold for a wide variety of shocks, insofar as a log-linear approximation to the equilibrium conditions of the model is valid (as I assume in all my numerical work). In this section, I use this empirical strategy to test whether the interest rate transmission mechanism can explain the observed effects of U.S. output innovations on the Canadian economy.

3.1. Effects of U.S. business cycles on the Canadian economy

The first step in testing the empirical success of the interest rate transmission mechanism is to estimate the response of the Canadian economy to a U.S. output shock. I measure U.S. output by its real GNP and seek effects of innovations in this variable. I assume that I can plausibly treat innovations to U.S. GNP as exogenous based on the view that the Canadian economy is too small to affect this variable. Hence innovations in U.S. GNP can be regarded as exogenous shocks to the Canadian economy. Further, I model the logarithm of real U.S. GNP as a univariate trend-stationary stochastic process. I estimate it as

$$\underset{}{Y_t^{US}} = \underset{(0.12)}{0.41} + \underset{(0.00013)}{0.00038}\, t + \underset{(0.071)}{1.32} Y_{t-1}^{US} - \underset{(0.070)}{0.38}\, Y_{t-2}^{US} + \eta_t^{US} \tag{12}$$

$DW=1.95$	$R^2=0.99$
$Q(36)=25.47$	Signif. level
Quarterly Data, 50:1–94:4	168 usable observations

My assumption that U.S. output contains a deterministic trend implies that innovations to output have only temporary—though persistent—effects. Alternatively, I could have assumed that output contains a stochastic trend, so that innovations to output have permanent effects. In that case, I would have also needed to change the specification of the model economy to incorporate the assumption of a stochastic trend because in the model presented in Section 2 it is explicitly assumed that trend growth is deterministic. Since the existence of a unit root in U.S. output remains controversial (see Rudebusch, 1993) it is not clear that the assumption of a stochastic trend is preferable to the assumption of a deterministic trend.

I interpret the error term in the U.S. GNP equation, η_t^{US}, as representing an average of structural disturbances to U.S. output, which could be the result, for example, of fiscal, monetary, or technological shocks or any combination thereof. The interpretation does not matter for the predictions of the theoretical models that are considered here. I am interested in the effect that η_t^{US} has upon Canadian investment, output, total hours, exports, imports, and the terms of trade. Real investment is defined as business inventory investment plus business investment on fixed capital and output as real gross domestic product. The hours data is based on total actual hours worked in all jobs. I approximate Canadian exports to the United States and Canadian imports from the United States by total Canadian exports and total Canadian imports.[6] On average 70 percent of Canada's total trade is with the United States. The terms of trade are defined as the ratio of export to import prices.[7] All series are quarterly, begin in the first quarter of 1950, end in the fourth quarter of 1991 and are taken from the *National Income and Expenditure Accounts* with the exception of the total hours series, which starts in 1975 and is taken from the *Labour Force Survey*. The data sources are described in more detail in the appendix.

To estimate the responses of the Canadian variables to innovations in U.S. output I estimate bivariate relationships between the logarithm of real U.S. GNP and the logarithm of my Canadian variables. In these regressions, the logarithm of each particular variable is explained by two lagged values of the variable, the current and two lagged values of the logarithm of U.S. output, a linear trend, and a constant.[8] I then calculate the response of a particular Canadian variable to a unit impulse in U.S. output by combining the estimated coefficients of (12) with those of the regression that explains the behavior of that variable.

The identification of the innovation to U.S. output, η_t^{US}, does not imply that η_t^{US} is necessarily orthogonal to all other shocks (omitted from the explicit model) affecting the Canadian economy directly. Thus, effects of η_t^{US} on Canadian macroeconomic aggregates could either be the result of economic transmission through goods and financial market interaction or reflect the fact that η_t^{US} is correlated with other exogenous variables, omitted from the regression, that affect the Canadian economy directly, or both. That is, even if both countries lived in autarky, one might observe comovements in macroeconomic aggregates similar to those estimated in my bivariate VAR. The strategy I pursue in this paper, however, is to assume that all the effects of η_t^{US} on the Canadian economy are due to economic transmission via financial and goods market trade and then to ask

[6] Data on bilateral trade between the United States and Canada is available for merchandise trade since 1971. Merchandise trade covers about 80 percent of total trade. This series is perhaps closer to total bilateral trade but has the disadvantage of starting only in 71:1, and therefore I do not use it.

[7] Time series for the export and import price indices for bilateral trade between the United States and Canada exist, but I do not use those series because they begin only in 1986.

[8] The adequate lag-length was determined by applying a likelihood ratio test.

whether the transmission mechanisms of several widely used equilibrium models of the international business cycle can quantitatively explain those observed effects.

3.2. The impulse responses predicted by the theoretical model

The second step in testing the empirical success of the interest rate transmission mechanism is to compute the response of Canadian macroeconomic aggregates predicted by the theoretical model to an innovation in U.S. output. According to the interest rate transmission mechanism, innovations to U.S. output affect equilibrium in the Canadian economy through their effects on the rate of interest on international financial assets available to Canadian agents. An appealing feature of the interest rate transmission mechanism is that it can operate in a one-sector economy. In fact, changes in investment opportunities in the foreign economy and wealth effects are the only potential transmission mechanisms in a one-sector framework (besides correlation of the underlying shocks). This observation is true independently of whether the model used is a small, open economy (as is the model analyzed here) that faces an exogenous world interest rate or a two-country model in which the supply schedule of financial assets is not perfectly elastic but rather is upward sloping.

To compute the impulse responses implied by the model economy to an innovation in U.S. output, the coefficients of the log-linearized equilibrium conditions as well as the exogenous stochastic process for the international interest rate $\{R_t\}$ must be calibrated. U.S. output itself does not enter the equilibrium conditions of the economy described in Section 2, however, it is assumed to affect equilibrium in that economy indirectly through the dependence of the exogenous process $\{R_t\}$ on U.S. output. Hence, to characterize the response of the model economy to innovations in U.S. output, one must estimate the stochastic process of the international interest rate taking into account its dependence on U.S. output. To be consistent with the estimations of the impulse responses above, a bivariate vector autoregression of U.S. GNP and the international interest rate is estimated assuming that U.S. GNP is the exogenous variable. I use two alternative measures of the international interest: the three-month Treasury bill rate and the quarterly S&P500 return index, each deflated by the devaluation rate of the Canadian dollar and the Canadian gross domestic product deflator. Let y_t^{US} denote the logarithm of detrended U.S. real GNP and R_t^T and R_t^S denote the logarithm of the Treasury bill and S&P500 based gross interest rates, respectively. Using quarterly data from 1956:2 to 1991:4, the estimation of the bivariate VAR yielded the following process for the world interest rate:[9]

[9] y_t^{US} denotes deviations from a deterministic trend. The coefficients on lagged values of U.S. output in the interest rate equation were small and insignificant and were therefore omitted from the regression.

$$R_t^S = \underset{(0.007)}{0.02} + \underset{(0.08)}{0.07}\, R_{t-1}^S - \underset{(0.08)}{0.11}\, R_{t-2}^S - \underset{(0.15)}{0.45} y_t^{US} + \eta_t^S$$

$DW = 2.02$		$R^2 = 0.08$
$Q(35) = 35.35$	141 usable observations	Significance level of $Q = 0.45$

$$R_t^T = \underset{(0.001)}{0.002} + \underset{(0.084)}{0.37}\, R_{t-1}^T + \underset{(0.084)}{0.08}\, R_{t-2}^T - \underset{(0.028)}{0.05} y_t^{US} + \eta_t^T$$

$DW = 2.01$		$R^2 = 0.22$
$Q(35) = 49.19$	141 usable observations	Significance level of $Q = 0.06$

U.S. output enters both interest rate equations significantly. If the measure of the world rate of interest is based on the equity return index, an innovation of 1 percent in U.S. GNP decreases the gross rate 0.45 percent, and if the measure of the world interest rate is based on the three-month Treasury bill rate, it decreases only 0.05 percent.[10]

A further input needed to compute the impulse responses implied by the theoretical model is the coefficients of the log-linearized equilibrium conditions. These coefficients are all functions of twelve free parameters, which can be grouped into five parameters that are matched up with long-run averages of the Canadian economy, six parameters that describe preferences, and one parameter that describes the adjustment cost technology (see Table 1). In the first group are the steady state world real rate of return, $r(\equiv R-1)$, the depreciation rate on capital, δ, the steady state per capitalreal income growth rate, $g(=\gamma_z-1)$, the steady state labor share, s_H, and the steady state ratio of net foreign interest receipts to gross domestic product, s_R. The steady state world interest rate is set at 4 percent per year and the depreciation rate at 10 percent. Postwar per capita real income growth in Canada was 1.6 percent per year on average, and the share of labor in gross domestic product was 0.68 on average.[11] The average share of net interest payments received, s_R, was -0.02, so that Canada was a net borrower in the international financial markets. These parameter values imply that the capital share is 0.32. In steady state, (10) and (11) using $s_K \equiv F_K K/F$ and $\varphi(\gamma_z)=\varphi'(\gamma_z)=0$ yield $(r+\delta)=s_K K/F$. The steady state share of investment in GDP, $s_I=(g+\delta)K/F$, can then be computed as $(g+\delta)/(r+\delta)s_K$, which is 0.23. The steady state

[10] I analyze impulse responses to η_t^{US} (which affect R_t^T [or R_t^S] through their effect on y_t^{US}) and not to η_t^T (or η_t^S) because these are innovations to the interest rate that are uncorrelated with innovations in U.S. output.

[11] The labor share is measured as the mean of the ratio of wages, salaries, and supplementary labor income to net domestic income at factor prices.

Table 1
Calibrated parameters

Parameter	Definition	Value	Description
Common parameters:			
r		0.04	Steady-state real rate of return (per annum)
δ		0.1	Depreciation rate of capital (per annum)
g		0.016	Steady-state per capita consumption growth rate (per annum)
s_H	$\dfrac{F_H H}{F}$	0.68	Share of labor income in GDP
s_R	$\dfrac{rB}{F}$	-0.02	Share of net interest income received in GDP
ϵ_{CC^h}	$\dfrac{X_c X_{C^h}}{X X_{CC^h}}$	∞, 4	Elasticity of substitution between home and market produced consumption goods
ϵ_{FH}	$-\dfrac{\partial C^h}{\partial H}\dfrac{H}{C^h}$	5/6	Elasticity of home goods with respect to hours supplied to the market
ϵ_{FH1}	$\dfrac{\partial^2 C^h/\partial H^2}{\partial C^h/\partial H} H$	1/6	Elasticity of the marginal product of home production
σ		1.5	
ϵ_{b1}	$u'(X)X$	0.001	Elasticity of the discount factor with respect to consumption
ϵ_{b2}	$\dfrac{u''(X)X}{u'(x)}$	-1	
π	$\varphi''(1+g)$	*	Second derivative of adjustment cost function
Additional parameters: two-sector model			
s_{EX}	$\dfrac{x^{d*}}{F}$	0.23	Steady-state share of exports in GDP
$\dfrac{1}{1+\rho}$	∞, 1.5		Elasticity of substitution between imported and exported goods
Additional parameters: implicit collusion model			
μ		1.4	Steady-state (value added) markup
ϵ_μ		0.35	Elasticity of the markup w.r.t. $(\Pi/p^d Y)$
α		0.9	Probability that collusion will continue

* The value of π is different across models and calibrations. In each case it is chosen so that the impulse response of investment predicted by the model is as close to the estimated impulse response of investment as possible.

version of (5) yields $s_C = 1 - s_I + (r-g)/rs_R$, which given the other parameter values is equal to 0.75.

It is convenient to assume that market- and home-produced consumption goods are perfect substitutes ($\epsilon_{cc^h} = \infty$) because in that case the parameter ϵ_{FH_1} $(\equiv f''(l)H/f'(l))$ can be interpreted as the negative inverse of the elasticity of hours with respect to wage, ϵ_{HW}, which is a parameter regularly calibrated in real business-cycle models. Assuming further a particular functional form for the home production function,[12] ϵ_{FH_1} and $\epsilon_{FH}(\equiv f'(H)H/f(H))$ are both functions of two parameters: ϵ_{HW} and the ratio of time worked in the market to time worked at home. Benhabib et al. (1991) assign a value of 33 over 28 for the latter parameter based on evidence from the Michigan Time Use Survey. The labor supply elasticity is set to 6, which is on the upper end of the range of values used in other other real business-cycle models (that use a finite value for this parameter) and clearly higher than the value estimated using micro data on individual labor supply. With a high labor supply elasticity, the model economy will predict relatively large employment increases for a given shift in the labor demand schedule.

The remaining preference-related parameters are the degree of homogeneity of the period utility function, $1-\sigma$, the elasticity of the discount factor with respect to the composite consumption good, $\epsilon_{b1}\equiv v'(x)x$, and $\epsilon_{b2}\equiv v''(x)/v'(x)x$.[13] The value given to σ is 1.5. A consequence of assuming that the discount rate is increasing in current consumption is that the elasticity of the discount factor has to be positive, but beyond this I have no further restrictions on its value. A value of zero would correspond to a constant discount factor model; I set it arbitrarily at 0.001. Similarly, from the assumed concavity of $v(.)$, ϵ_{b2} has to be negative; and in the absence of further restrictions I set it equal to minus one.[14] The final parameter to be calibrated is the second derivative of the adjustment cost function evaluated at γ_z, π. Again, I have little independent evidence on which to base a value for this parameter. The value is assigned so as to maximize the fit of the computed investment impulse response.[15]

3.3. Comparing predicted and estimated impulse responses

The final step in testing the empirical success of the interest rate transmission mechanism is to compare the estimated and the predicted impulse responses of the Canadian economy to an innovation in U.S. output. The exogenous stochastic process for U.S. output and the international interest rate together with the log-linearized equilibrium conditions of the model imply that the model solution has an MA(∞) representation in the orthogonal innovations η_t^{US} and η_t^S (or η_t^T). In comparison, the atheoretical bivariate vector autoregression implies that the

[12] $\tilde{C}_t^h = f(l_t) = (\bar{H} - H_t)^w/w$, $0<w<1$.

[13] By assumption, $v''<0$, $v'>0$ and $x>0$ and, hence, $\epsilon_{b1}>0$ and $\epsilon_{b2}<0$.

[14] A sensitivity analysis (see Schmitt–Grohé, 1995) reveals that the predictions of the model are rather robust to variations in ϵ_{b1} and ϵ_{b2}.

[15] This parameter value was set individually for each parameterization for which model predictions are reported below. I chose the value of π so that the model predicts the investment response as well as possible given other parameter values and the process of the international interest rate. For the S&P500 based interest rate measure π is 85 if $\epsilon_{cc^h}=\infty$ and 80 otherwise; for the T-Bill interest rate measure π is 16 if $\epsilon_{cc^h}=\infty$ and 14 otherwise.

Canadian variables have an MA(∞) representation in the orthogonal innovations η_t^{US} and ϵ_t, where ϵ_t is the residual in the regression of the Canadian variable on its own lags and current and lagged values of U.S. GNP. Comparing the predicted and the estimated impulse responses to an innovation in U.S. output thus tests whether the MA coefficients associated with η_t^{US} are the same in the model as in the data. I focus on the impulse responses in the first 10 quarters after the innovation.

Predicted and estimated impulse responses of Canadian investment, output, and hours to a unit innovation in U.S. output are presented in Fig. 1. The predicted impulse response is shown for both measures of the international interest rate. These plots also show a two standard error confidence interval around the estimated impulse response to give a sense of how well the model performs.[16] Panel (a) in the left column of Fig. 1 shows that the adjustment cost parameter can for both interest rate measures be set in such a way that the predicted or computed impulse response of Canadian investment follows the estimated impulse response closely. In contrast, the computed responses for gross domestic product and hours (panels (b) and (c) in the left column of Fig. 1), though right in direction, are far below the respective lower bound of the estimated impulse response confidence intervals. A one percent innovation in U.S. output results in an estimated increase in Canadian output of about 1 percent after four quarters. Since in the period of impact the labor demand schedule is fixed (because the capital stock is predetermined), any variation in output has to be due to shifts in the labor supply schedule. However, under the maintained assumption that consumption of the market- and the household-produced good are perfect substitutes, labor supply is only a function of the real wage. Therefore, the model predicts a zero response of output and employment in the period of impact. In the following periods the labor demand schedule shifts out, where the size of the shift is determined by the increase in capital. Given the same response for investment and, hence, for the capital stock under both interest rate response estimates (due to the appropriate choice of π), the model will predict the same increase in employment and output for both interest rate responses. Even though output is above its steady state value from period 2 on, the increases in the capital stock are not sufficiently large for this model, or this transmission mechanism, to explain the size of the estimated increase in output and employment.

For the model to predict a larger increase in output and employment would require an increase in labor supply for any given wage. Such an increase in labor supply could occur if the innovation in U.S. output increases the marginal utility of

[16] The standard error bands are asymptotic confidence intervals based on Gaussian approximations to the distribution of the responses. I also computed error bands based on Bayesian posterior probability intervals to check for potential asymmetries in the distribution of the impulse responses. The probability intervals were—for the purposes of my analysis—very similar to the asymptotic confidence bands.

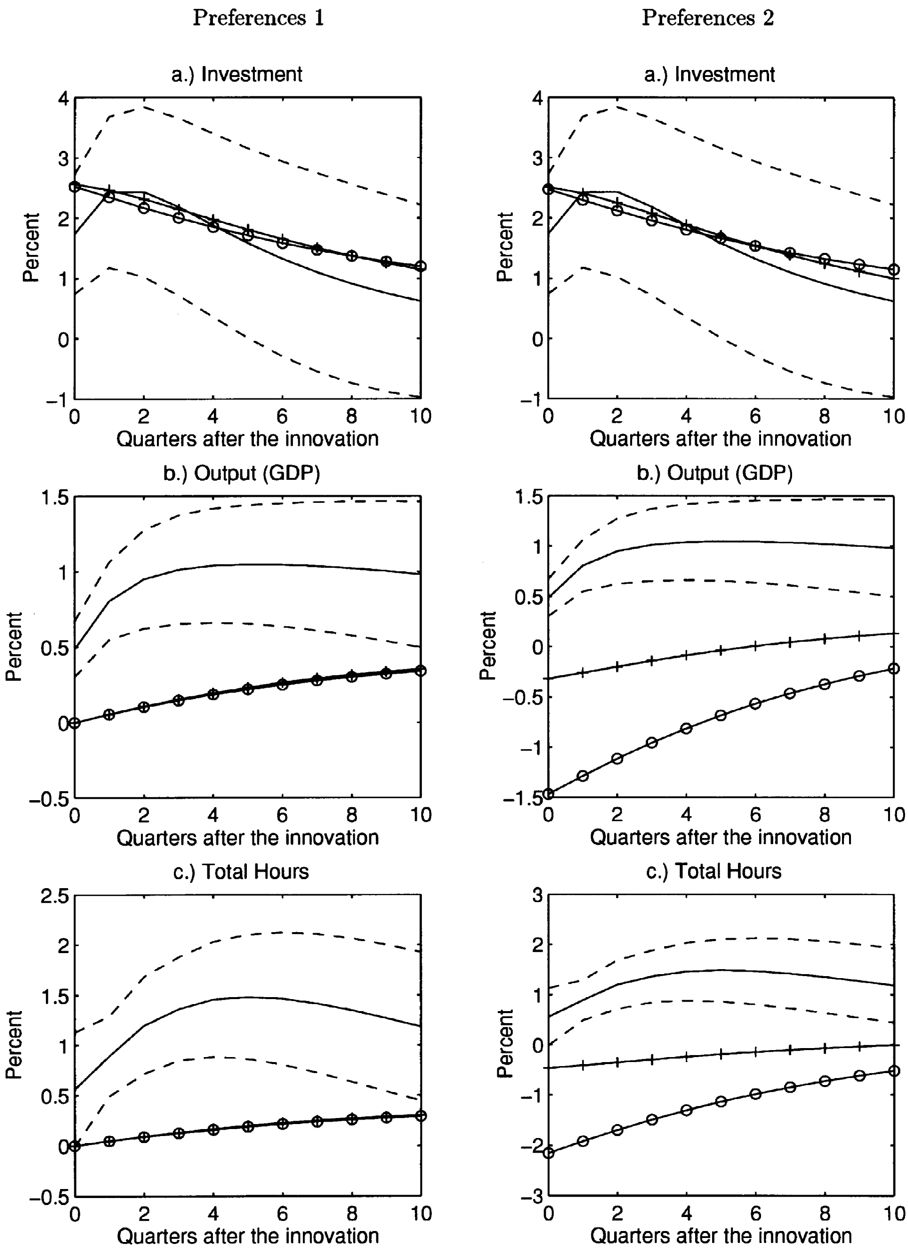

Fig. 1. Estimated and predicted impulse responses, transmission channel: Financial markets: (——) estimated impulse response, (- - -) estimated impulse response ±2 std. errors, (o-o-o) predicted impulse response, interest rate measure: S&P 500, and (+-+-+) predicted impulse response, interest rate measure: T-Bill.

income and labor supply depends positively on the marginal utility of income. Assuming that consumption of home-produced and market-produced goods are imperfect substitutes will imply the latter. The computed responses are repeated (in the right column of Fig. 1, labeled Preferences 2) assuming that the elasticity of substitution between home-produced and market-produced consumption goods is equal to 4.[17] With the appropriate choice of the adjustment cost parameter, the predicted investment response again matches the estimated one well but the model predicts a decline in output and employment for both proxies of the rate of return on the international asset. The reason for the decline in employment is that interest rates fall in response to the positive innovation in U.S. output (from the VAR estimation), so that agents substitute current consumption for future consumption and the marginal utility of income declines. The size of the increase in current consumption depends on the size of the predicted decline in the rate of return on the international asset, and therefore the marginal utility of income falls more for the S&P500 based world interest rate measure than for the Treasury bill based world interest rate measure. This explains why output and employment fall by more when the rate of return on the international asset is approximated with the S&P500 index. Finally, for both preference specifications, the response of investment, output, and hours is rather persistent. High first-order serial correlation in this model is not a consequence of the highly persistent process for the exogenous variable, U.S. GNP, but rather of the relatively inelastic rate of time preference.[18]

The rejection of the one-sector model with financial markets as the sole transmission channel is independent of the uncertainty involved in estimating the interest rate response to the U.S. output innovation. Suppose that the two estimations for the response of the rate of return on the international asset presented above were wrong even in direction and that the correct response was an increase rather than a decrease. In this case the model would wrongly predict Canadian investment to decline regardless of the adjustment cost parameter chosen. Therefore, the result of this section is that the one-sector, open-economy model cannot explain the observed response of Canadian output, hours, and

[17] In this case, ϵ_{FH} and ϵ_{FH_1} cannot be shown to be functions only of the elasticity of hours with respect to the real wage and the ratio of home-work to market-work. The parameter values are unchanged to isolate the effect of changing the degree of substitutability between market- and home-produced consumption goods.

[18] As is well known, a small-open-economy model in which the subjective discount rate is constant and equal to the world interest rate implies that consumption among other variables has a unit root. The endogenous rate of time preference eliminates this unit root but produces short-run dynamics that are similar to those of a constant discount factor model. For example, for preference specification 2, the conditional first-order serial correlations of Canadian output, investment, and hours—conditional on innovations to U.S. output being the only disturbance to the economy—exceed 0.95 regardless of whether U.S. output is assumed to be highly persistent (as estimated from the VAR) or is assumed to be an i.i.d. process.

investment to a unit innovation in U.S. output regardless of what one assumes about the interest rate response. A more successful model would require that labor demand shift by more in response to the U.S. output innovation. This idea will be explored in the next section, where labor demand is also a function of the terms of trade and potentially of the markup of prices over marginal costs.

4. Additional channels for the international transmission of economic fluctuations

4.1. Export markets

Terms-of-trade variations as a potentially important channel for transmission of disturbances between national economies have a long tradition in international economics. This section assumes that the terms of trade are endogenous and analyzes whether changes in them caused by variations in export demand can explain the transmission of U.S. business cycles to the Canadian economy.

4.1.1. A two-sector model

I modify the previous model as follows: Consumers and firms (for investment purposes) are assumed to have CES preferences over the good produced exclusively by Canada, the export good, and the good produced by the United States, the import good. A given total expenditure, E_t, on goods is divided across the two goods so as to maximize

$$[(x_t^d)^{-\rho} + (x_t^f)^{-\rho}]^{-(1/\rho)}, \quad \rho \geq -1 \tag{13}$$

subject to the budget constraint $p_t^d x_t^d + p_t^f x_t^f = E_t$, where x_t^i denotes purchases of good $i = d,\ f,\ p_t^i$ denotes the price of that good, and E_t denotes either total expenditures on consumption of the representative consumer or total expenditures on investment. As before, the economy is made up of a large number of identical, infinitely-lived households, and the representative consumer seeks to maximize (1), where C_t now denotes the value of the two goods defined above by (13). Prices are normalized so that the price of C_t equals one. Domestic demand for the exported and imported good for consumption and investment purposes has to satisfy (from the solution to Eq. (13))

$$\left(\frac{x_t^d}{x_t^f}\right) = \left(\frac{p_t^d}{p_t^f}\right)^{(-1/(1+\rho))}$$

Similarly, it is assumed that the aggregate U.S. demand for consumption and investment is of the same form so that

$$\left(\frac{x_t^{d*}}{x_t^{f*}}\right) = \left(\frac{p_t^d}{p_t^f}\right)^{(-1/(1+\rho))}$$

where x_t^{d*} denotes the U.S. demand for Canada's export good, and x_t^{f*} denotes aggregate U.S. demand for its national good. I identify x_t^{f*} with U.S. GNP. Shocks to U.S. output thus affect the determination of equilibrium in the small country directly, and a response in the rate of return on international financial assets is no longer necessary to connect the two economies. The one-sector economy is a special case of this economy, in the event that the elasticity of substitution between the import good and the export good is infinite ($\rho = -1$).

Along a balance growth path the terms of trade, (p_t^d / p_t^f), are constant only if I assume that the steady state growth rate of U.S. GNP coincides with that of the Canadian economy. Exports and imports will share the common trend of the other variables and can be transformed into stationary variables by dividing by z_t.

4.1.2. Testing transmission through terms-of-trade variations

The coefficients in the log-linear approximation to the equilibrium conditions are functions of two parameters more than in the one-sector model. One additional parameter is the steady-state share of exported goods in gross domestic product, which I calculated by taking the average ratio of Canadian exports to GDP for the period 1960 to 1991. The value assigned is 0.23. The other free parameter is the elasticity of substitution between export and import goods. A value of 1.5 was assigned to this parameter. The predictions of the model economy will depend on the estimated U.S. GNP response, which was described in Section 3.1. I assume that the rate of return on the international bond is not affected by the innovation in U.S. output in order to isolate variations in export demand as the transmission channel.

I compare the model's predictions of output, investment, hours, exports, imports, and terms of trade to those generated by the vector autoregressions discussed above. Fig. 2 presents the response of Canadian variables to a 1 percent innovation in U.S. GNP in the case that home-produced and market-produced consumption goods are perfect substitutes (preferences 1). Variations in export demand as the transmission mechanism can produce an investment response just inside the two standard error confidence bands and, at the same time, lead to positive responses for output and employment that are greater than the respective responses triggered by transmission through variations in the interest rate. However, the computed impulse responses for output and hours are still below the two standard error confidence bands.

This model also has testable implications for the behavior of exports of the Canadian good to the United States, imports of the U.S. good to Canada, and the terms of trade. The model correctly predicts the import response in the period of impact and underpredicts it in the subsequent periods. Terms of trade is the only

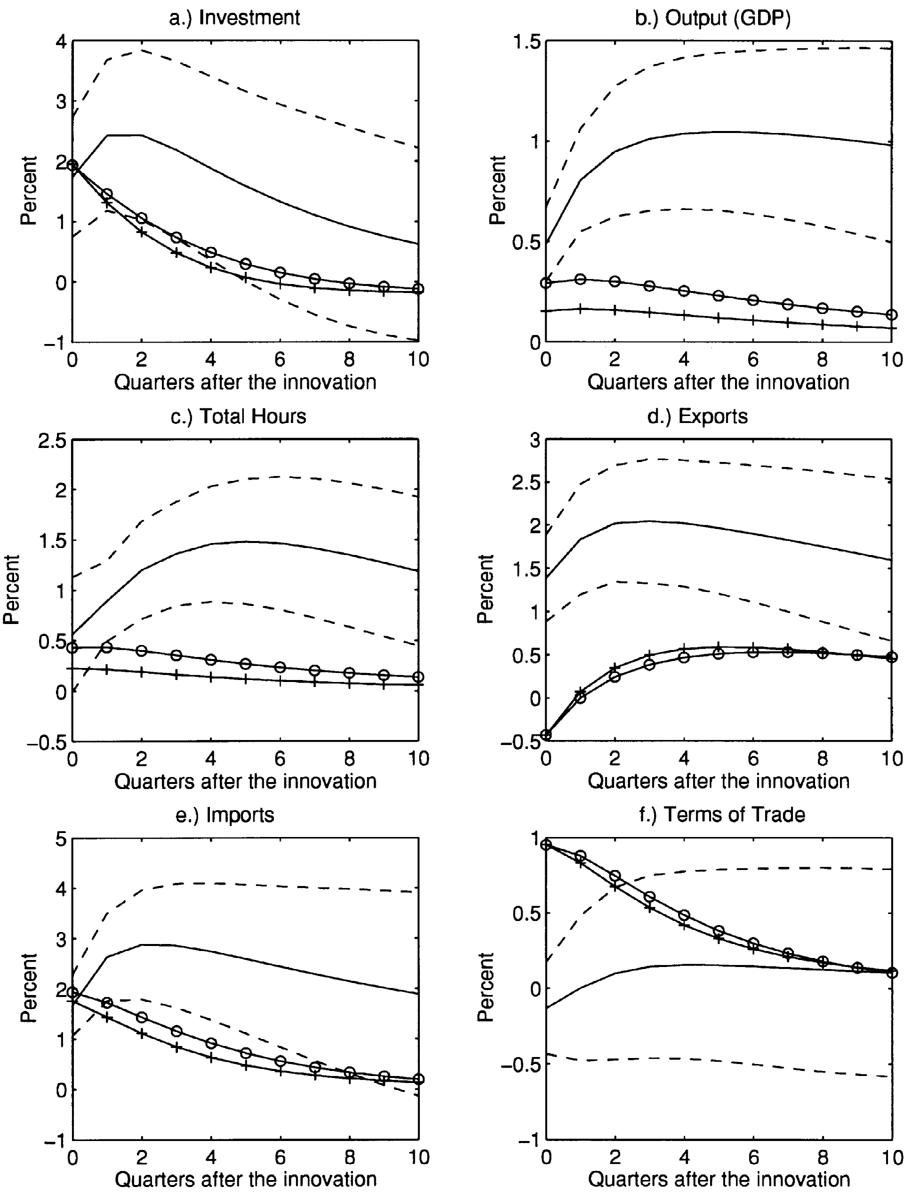

Fig. 2. Estimated and predicted impulse responses, transmission channel: Export-demand variations: (——) estimated impulse response, (- - -) estimated impulse response ±2 std. errors, (o-o-o) predicted impulse response, preferences 1, and (+-+-+) predicted impulse response, preferences 2.

variable for which I cannot estimate a significant response. The point estimate of the terms-of-trade response is negative on impact but small and insignificant. The predicted terms-of-trade response in the period of impact is substantially higher than estimated. The model economy predicts an increase in the terms of trade of close to 1 percent whereas the upper bound of the confidence interval around the estimated response is only 0.2.

A discrepancy between estimated and computed responses even in direction exists for exports. Whereas exports are estimated to rise 1.4 percent on impact, the model predicts a decline of 0.42 percent. The explanation for this discrepancy is that, while the innovation in U.S. output raises the U.S. export demand, it also stimulates domestic demand for the export good, and with the particular parameter values chosen here, the price of the export good appreciates so much that U.S. demand gets crowded out initially. To reproduce the observed response in hours in the period of impact, however, the model economy would require an even larger appreciation in the terms of trade, and conversely, to correctly predict the lower observed response in the terms of trade, the model economy would require a greater increase in hours for the given increase in export demand or a more elastic supply of the export good. The model correctly predicts an increase in exports in the periods following the increase in U.S. demand. However, the predicted increase is much smaller than the estimated one. As in the previous subsection, impulse responses are also computed for preference specification 2. The predicted impulse responses are similar to preferences 1 because the interest rate is unchanged and hence the labor supply schedule does not shift by much.

Suppose that the terms of trade are not endogenous as assumed so far but are determined on the world market and thus are exogenous for the small-open economy. Then an alternative channel through which disturbances to the U.S. economy could be transmitted to the Canadian economy are exogenous variations in the terms of trade. Although I do not analyze this case here, the previous findings suggest that this transmission channel would not be any more successful than the variations of export demand transmission channel. One would again run into the problem, that for the estimated impulse response of the terms of trade, the output and hours responses predicted by the theoretical model would be below the observed responses for these two variables.

This paper is not the first to show that a two-sector international real business-cycle model cannot account at the same time for the behavior of output and the terms of trade. Backus et al. (1994) demonstrate that a two-country, two-sector international real business-cycle model driven by technology shocks that are positively correlated across countries predicts that terms of trade are less volatile than output, whereas in postwar data for several OECD countries the opposite is true, that is, the terms of trade tend to be more volatile than output. Combining my findings with those of Backus, Kehoe, and Kydland suggests that this model produces too much terms-of-trade variation in response to export-demand shocks and too little terms-of-trade variation in response to technology shocks.

4.2. Imperfectly competitive export markets

Thus far, the assumption has been that product markets are perfectly competitive, which is the standard assumption in the literature on closed as well as open economy real-business-cycle models.[19] One implication of this assumption in the open economy model developed here is that there are only two potential sources of shifts in the labor demand function: (1) increases in capital over time and (2) increases in the terms of trade. The first source cannot produce a positive response in hours in the period of impact because capital is predetermined. For the periods following the shock, the observed response of investment is quantitatively not large enough for the model to be able to explain the observed output and employment increases, as the above analysis has shown. Similarly, the predicted variations in the terms of trade induced by the U.S. output innovation (together with the subsequent increase in capital) are not large enough to account for the observed output and hours responses either.

Several authors have noted that perfectly competitive models offer a poor explanation for comovements of hours, wages, and output following demand shocks. Since the increased demand by the United States for Canadian value added is a demand shock, one is led to look at models that have been proposed to address this particular weakness of the competitive model. One of those is the model of implicit collusion by Rotemberg and Woodford (1992). Rotemberg and Woodford show that effects of government purchases shocks on economic activity can be better understood with their model of countercyclical markups than with models of perfect competition and several other models of imperfect competition. In this section, I ask whether the particular kind of imperfect competition modeled in Rotemberg and Woodford (1992) also helps to explain the observed transmission of U.S. disturbances to Canadian economic activity. The reason that it should is that it implies that equilibrium markups decline in response to positive aggregate demand shocks, and this decline in markups may shift the labor demand schedule enough to explain the observed increase in hours and output in the absence of a significant terms-of-trade appreciation.

4.2.1. The implicit collusion model of Rotemberg and Woodford

To follow the experiment that I conduct here, it is only necessary to know that in the Rotemberg–Woodford model export producers have market power and implicitly collude in setting the price of the export good.[20] The presence of market power implies that price exceeds marginal cost, and implicit collusion in setting

[19] There are some exceptions. Models of the business cycle with imperfect competition include Farmer and Guo (1994); Galí (1994); Head (1994); Hornstein (1993); Rotemberg and Woodford (1992).

[20] For a detailed description on how to embed the Rotemberg–Woodford model into a small open economy framework, see Schmitt–Grohé (1995).

the price of the export good can be shown to imply that the equilibrium markup—that is, the ratio of price over marginal cost—is an increasing function of the ratio of the present discounted value of future profits Π_t, to current sales $p_t^d Y_t$

$$\mu_t = \mu\left(\frac{\Pi_t}{p_t^d Y_t}\right) \tag{14}$$

The reason the markup, $\mu(.)$, is increasing in this ratio is that, when current sales are high relative to future profits, the incentive for the oligopolistic export producer to deviate from the collusive agreement is greater and hence the sustainable markup is lower. Export producers have access to the following production technology:

$$Y_t = F(K_t, z_t H_t) - \phi_t$$

where $F(.)$ is homogeneous of degree one in capital and labor and ϕ_t denotes fixed costs. From the firm's cost-minimization problem, labor demand is given by

$$p_t^d F_H(K_t, z_t H_t) z_t = \mu_t w_t$$

In the implicit collusion model there are thus three potential shifters of the labor demand schedule: the capital stock, K_t; the terms of trade, p_t^d; and the endogenous markup, μ_t. The remaining equilibrium conditions of this model are straightforward modifications of those of the two-sector economy presented above. The two previous models can be nested in this one: setting the steady state markup to one the implicit collusion model collapses to the two-sector competitive model used to study transmission through export-demand variations and setting, in addition, the elasticity of substitution between import and export goods to infinity the model collapses to the one-sector competitive model used to study transmission through interest rate variations.

4.2.2. Testing transmission through variations in market power

In calculating the quantitative prediction of this model for the response of Canadian economic activity to a unit innovation in U.S. output, I assume that in steady state profits are zero, $p^d\tilde{Y}=\tilde{w}H+u\tilde{K}$, which implies that $\mu\tilde{Y}=F(\tilde{K}, H)$ and that the degree of short-run firm-level increasing returns equals the markup.

The coefficients of the log-linearized equilibrium conditions then involve only three additional parameters: the steady state markup, μ; the elasticity of the markup with respect to $(\Pi/p^d Y)$, ϵ_μ(which as shown in Rotemberg and Woodford, 1992, has to satisfy $0<\epsilon_\mu<\mu-1$); and the probability that the collusive agreement will last, α. Rotemberg and Woodford (1994) discuss empirical evidence on the size of the markup and the degree of firm-level increasing returns, and I draw from their discussion to calibrate μ. For example, Domowitz et al. (1988) estimate gross output markups to be between 1.4 and 1.7; Morrison (1990) estimates gross output markups between 1.2 and 1.4. In fact, I have to calibrate a value-added markup which can be shown to exceed gross output markups. Hall (1988) and Basu and Fernald (1997) report estimates of value-added markups that are quite different from each other. Hall's estimates are above 1.8 for most of his one-digit industries, and Basu and Fernald estimate value-added markups of at most 1.26 for two-digit manufacturing industries. I follow Rotemberg and Woodford (1994) and use a value of 1.4 for μ. To calibrate ϵ_μ subject to the restriction $0<\epsilon_\mu<\mu-1$, I set it arbitrarily at 0.35. The calibration of the model involves one more parameter, namely α, the probability that the collusive agreement will last, for which I use a value of 0.9. I also present results for the case that the markup is constant (i.e., $\epsilon_\mu=0$). In this case, the equilibrium conditions can be interpreted as those of an economy with monopolistically competitive product markets.[21]

Fig. 3 presents the impulse response of Canadian economic activity to a unit innovation in U.S. output assuming that the innovation in U.S. output affects export demand but not the international interest rate, that is, transmission can occur through variations in export demand and through variations in the equilibrium markup, but not through interest rate variations. The figure shows the response for three model specifications—the implicit collusion model, the fixed markup model and the competitive model (reproduced from Fig. 2).[22] As in Figs. 1 and 2, one can choose the adjustment-cost parameter such that the computed impulse response of Canadian investment implied by the Rotemberg–Woodford model lies inside the two standard error band of the estimated response; the value of π is 3.

Given this choice of the adjustment-cost parameter, the implicit collusion model predicts that Canadian output increases by 0.7 percent in the period the innovation in U.S. output occurs, which is more than twice the increase in output predicted by the competitive model. Similarly, the implicit collusion model predicts an increase in total hours in the period of impact of 0.76 percent, whereas the competitive model predicts an increase in total hours of only 0.43. As anticipated, the implicit collusion model predicts a larger increase in output and hours than does the competitive model and at the same time predicts a lower terms-of-trade appreciation. When exporters do not have market power, the appreciation in the terms of trade is more than 50 percent larger than when exporters do have market power. In the collusive economy, the increase in U.S. demand for the Canadian good lowers the sustainable markup. Markups fall temporarily from 1.4 to 1.05.

The behavior of total hours and output now can be easily understood from equilibrium in the labor market. The decline of the domestic markup shifts the labor demand schedule out as does the appreciation of the terms of trade. The shift in the labor demand schedule is larger in the implicit collusion model than in the

[21] Like, for example, the economy with constant marginal cost presented in Hornstein (1993).

[22] The model predictions are for preference specification 1, which implies that labor supply is only a function of the wage and not of the marginal utility of income.

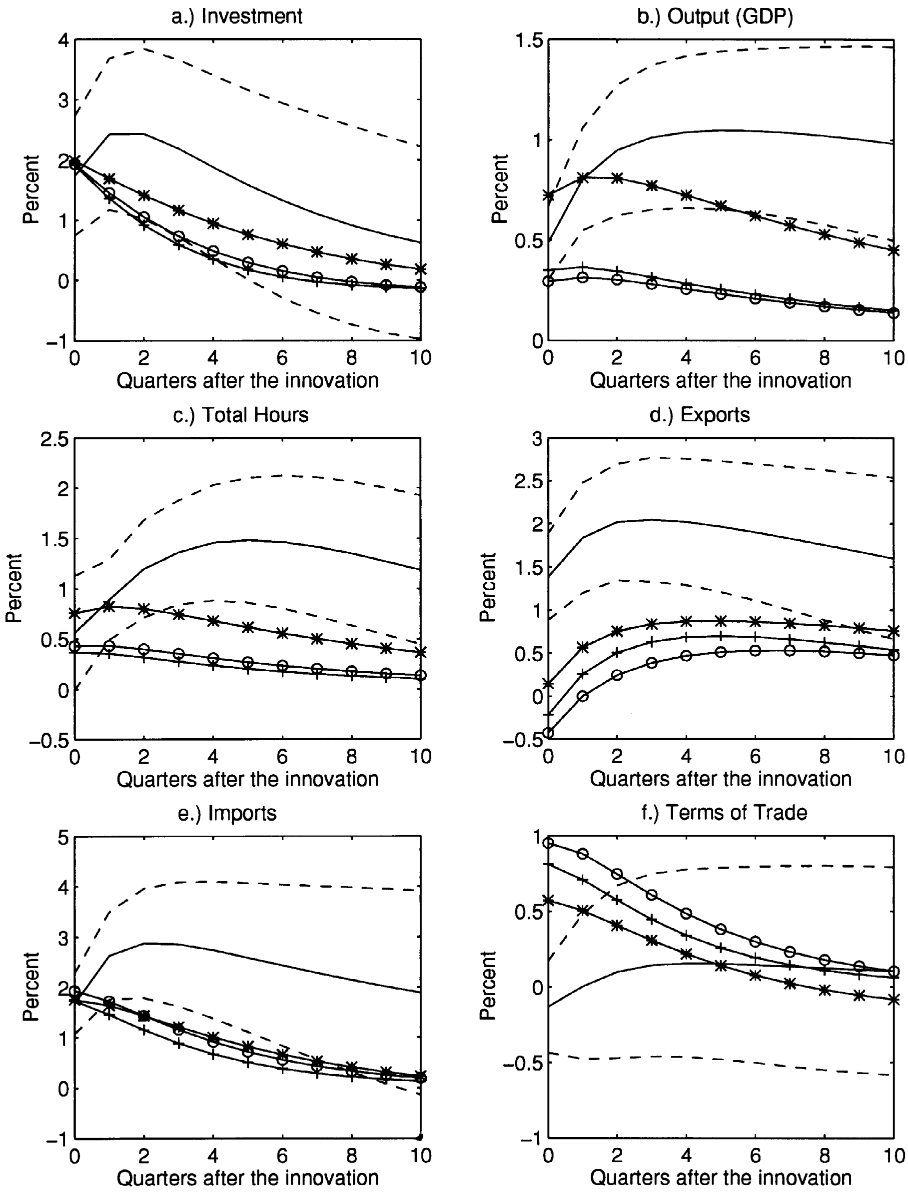

Fig. 3. Estimated and predicted impulse responses, transmission channel: Export-demand variations when exporters have market power: (——) estimated impulse response, (- - -) estimated impulse response ±2 std. errors, (o-o-o) predicted impulse response, constant markup of 1, (+-+-+) predicted impulse response, constant markup of 1.4, and (*-*-*) predicted impulse response, variable markup of 1.4 and elasticity of 0.35.

competitive model even though the terms-of-trade appreciation is smaller. Because labor supply is only a function of the wage rate, the labor supply schedule does not shift in response to the increase in export demand, and all movements in equilibrium hours and output (in the period of impact) are due to shifts in the labor demand schedule. The implicit collusion model correctly predicts that Canadian exports increase, whereas the competitive model predicts that they decline. This difference is a consequence of the smaller terms-of-trade appreciation. Although the introduction of a countercyclical markup brought estimated and model impulse responses of all six variables closer together, the improvement is quantitatively not large enough to solve the problem of correctly predicting hours, exports, and the terms of trade at the same time.

The introduction of imperfect competition with a fixed markup does not bring estimated and model impulse responses closer together.[23] As can be seen in Fig. 3, the only improvement of the fixed markup model over the competitive model is that the predicted terms-of-trade appreciation is smaller. This implies that a monopolistically competitive model with a fixed markup does not help overcome the shortcomings of the competitive model in explaining transmission of U.S. output shocks to the Canadian economy.

4.3. Transmission through financial and export markets

In this subsection, I compare the quantitative predictions of the competitive as well as the collusive model allowing for transmission through financial markets, export-demand variations, and possibly markup variations. The impulse responses of the theoretical economies to an innovation in U.S. output are computed using the response of the three-month Treasury bill rate as a measure of the interest-rate response. Fig. 4 shows the computed impulse responses for the competitive model, the implicit collusion model, and the monopolistic competition model. The adjustment cost parameter, π, can be chosen in each case so that the predicted investment response matches the estimated one reasonably well. Responses for output are above those based on the export-demand variations channel alone, and for all three models the computed responses are now within the two standard error confidence bands (at least for the first four quarters after the innovation). Without variations in the international interest rate the collusive model's predicted output response was the only one inside the two standard error band. The implicit collusion model still predicts the strongest increase in output and also shows the strongest increase over time in the output response. Similarly, the responses for hours are above those allowing only for transmission through export-demand variations.

---

[23] Rotemberg and Woodford (1994) make a related point. They show that imperfect competition alone does not magnify the short-run effects of innovations in government purchases on hours and output.

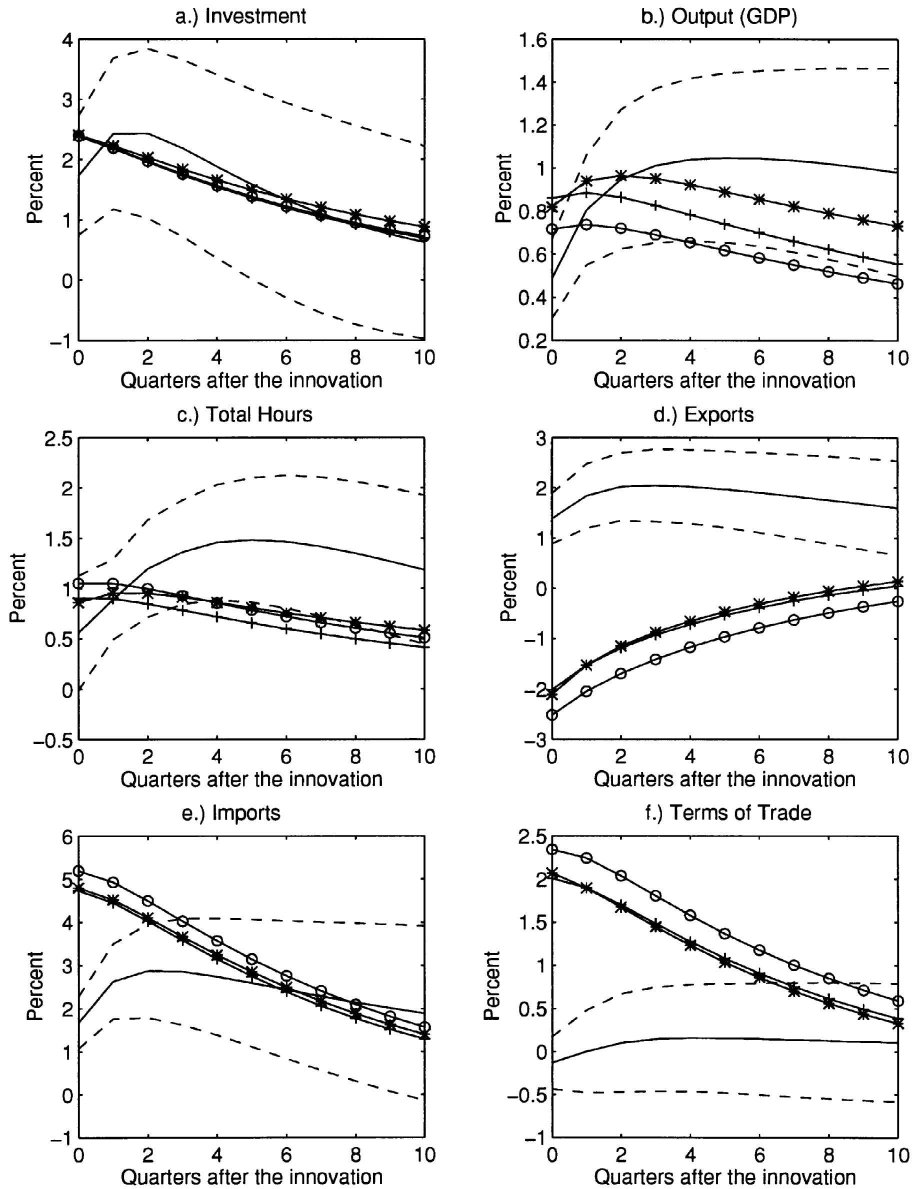

Fig. 4. Estimated and predicted impulse responses, transmission channel: Financial markets and export-demand variations together: (——) estimated impulse response, (- - -) estimated impulse response ±2 std. errors, (o-o-o) predicted impulse response, constant markup of 1, (+-+-+) predicted impulse response, constant markup of 1.4, and (*-*-*) predicted impulse response, variable markup of 1.4 and elasticity of 0.35.

As noted previously, the international rate of return drops in response to the positive innovation in U.S. economic activity. This decrease stimulates consumption because Canadian agents substitute current consumption for future consumption and also stimulates investment as the rate of return on domestic capital is temporarily dominating the international rate of return.[24] Therefore, the relative price of the export good increases more than it did when R_t was unchanged, as can be seen in panel (f). For the collusive model the predicted terms-of-trade appreciation now is 2, whereas it was .6 allowing for the export-demand variations channel only. Another consequence of the greater appreciation in the terms of trade is that now all models fail to predict the rise in exports.

The difference between the implicit collusion model and the constant markup model is perhaps less visible now than it was in Fig. 3; it is certainly not magnified. The reason is that now lower interest rates raise Π_t, the present discounted value of future profits under collusion, and hence $\Pi_t/p_t^d Y_t$ falls less, thus the decline in markups is smaller. This in turn implies that the shift in the labor demand schedule is reduced and that we are closer to the predictions of the fixed-markup model. Overall the implicit collusion model fits the data best, but the improvement over the competitive model is quantitatively not large relative to the distance between model and data impulse responses.

Finally, the results of a sensitivity analysis (see Schmitt–Grohé, 1995) suggest that variations in the preference parameters over a range that is considered interesting can only marginally change the predicted responses of the six macroeconomic variables considered. In particular, the failure of the model to predict a positive export response remains. A parameter that can affect the export response and make it positive is the export share. High values for the export share (above 60 percent), although resulting in a positive model prediction for the response of exports, either leave the performance of the other variables unchanged or improve it. However, such high export shares are hardly empirically realistic.

5. Summary and conclusion

This paper has investigated whether trade in international goods and financial markets alone can quantitatively explain the observed transmission of short-term economic fluctuations from the U.S. economy to the Canadian economy. The results presented suggest that, for transmission through financial markets and for transmission through export-demand variations individually, as well as for both transmission channels jointly, this is not the case—at least in the context of the three particular equilibrium business cycle models analyzed.

[24]For example, in the competitive model without financial markets as a transmission channel, Canadian consumption increases by 0.4 percent, and with the interest rate drop it increases by 2.6 percent.

When allowing for transmission through financial markets only, the predicted output and employment responses were too small compared to those estimated from postwar data for the small–large country pair Canada and the United States. When allowing for transmission through variations in export demand, the theoretical impulse responses for output and hours were closer to the estimated ones, but the predicted output and employment increases still fell short of the observed responses. Further, the predicted appreciation of the terms of trade was much stronger than the one observed, and the predicted export response was wrong even in direction.

This result is partially reversed once one allows for implicit collusion among the small country's export producers. In that case, transmission through export-demand variations alone can explain the quantitative response of investment, output, and hours simultaneously and the qualitative response of all six variables considered. The problem of predicting a too-strong terms-of-trade appreciation is alleviated but not solved.

If transmission occurs through both the financial-market and the export-demand channels, then regardless of whether or not exporters have market power, the models can account quantitatively for the response of Canadian output, investment, and employment. The predicted model responses suggest, however, that the models in this case require a stronger terms-of-trade response than that observed to account for the output and employment behavior. Further, the transmission channels together fail to predict the observed increase in exports. Therefore, I conclude that in the presence of both the financial-market and the export-demand channels, trade alone cannot explain the transmission of short-term fluctuations from the United States to Canada for all six variables studied in this paper.

The results suggest that one important reason for the failure of trade alone to explain the transmission of short-term fluctuations from the United States to Canada is that the observed responses in real quantities—such as investment, output, and total hours—are not accompanied by significant price movements; but the models analyzed here, regardless of whether product markets are perfectly or imperfectly competitive, predict substantial movements in investment, output, and hours only in the presence of a significant terms-of-trade appreciation. It is left for future research to explore whether relaxing the assumption of price flexibility reconcile the small observed response in the terms of trade with the strong observed response of output, investment, and hours.

Acknowledgements

This paper is based on chapter one of my doctoral dissertation at the University of Chicago. I am especially indebted to the members of my dissertation committee, Michael Woodford (chair), Lars Peter Hansen, and Thomas Sargent for their guidance and to Martín Uribe for many discussions. I would also like to thank

Robert Kollmann, Enrique Mendoza, and seminar participants at the University of Chicago, the Board of Governors, Georgetown, Cornell, Pompeu Fabra, Western Ontario, and the Canadian and European Economic Association 1994 meetings for comments. Financial support from the Alfred P. Sloan Doctoral Dissertation Fellowship is gratefully acknowledged. The opinions expressed in this paper are those of the author and do not necessarily reflect views of the Board of Governors of the Federal Reserve System or other members of its staff.

Appendix

Data sources

This appendix lists the data sources. All series consist of 168 quarterly seasonally adjusted observations from 1950:1 to 1991:4, unless noted otherwise.1. CANSIM, Statistics Canada, Ottawa.

1. CANSIM, Statistics Canada, Ottawa.

Cansim Series Title	Cansim − Databank identification number
Gross domestic product at 1986 prices	D20463
Business inventory investment at 1986 prices	D20473
Business investment on fixed capital at 1986 prices	D20468
Exports of Goods and Services at 1986 prices	D20476
Imports of Goods and Services at 1986 prices	D20480
Exports of Goods and Services, Price Index	D20570
Imports of Goods and Services, Price Index	D20573
Net domestic income at factor cost	D20001
Wages, salaries, and supplementary labour income	D20002
GDP, Implicit Price Deflator, 1986 = 100	D20556

2. Historical Labour Force Statistics, Statistics Canada, 1992.
   Employment Total Actual Hours Worked (all Jobs), 1992.
   Quarterly averages of monthly data. Series begins 75:1
3. Board of Governors of the Federal Reserve System
   U.S. dollar exchange rate (cents per Canadian dollar),
   Quarterly averages of weekly data, nsa, Series begin 56:1
4. CITIBASE: Citibank economic database

Series title	Retrieval code
Real gross national product	GNPQ
3 Month U.S. Treasury Bill (sec. mkt)(nsa) (monthly averages of daily data)	FYGM3

5. Ibbotson Associates Database
   S&P500 Total return index.

References

Ambler, S., 1989. Does money matter in Canada? Evidence from a vector error correction model. The Review of Economics and Statistics 71, 651–658.

Backus, D., Kehoe, P.J., Kydland, F.E., 1992. International real business cycles. Journal of Political Economy 100, 745–775.

Backus, D., Kehoe, P.J., Kydland, F.E., 1994. International business cycles: theory and evidence. In: Thomas Cooley (Ed.), Frontiers of Business Cycle Research. Princeton University Press, Princeton, NJ, pp. 331–356.

Basu, S., Fernald, J., 1997. Returns to scale in U.S. production: estimates and implications. Journal of Political Economy 105, 249–283.

Baxter, M., Crucini, M., 1993. Explaining saving—investment correlations. American Economic Review 83, 416–436.

Benhabib, J., Rogerson, R., Wright, R., 1991. Homework in macroeconomics: household production and aggregate fluctuations. Journal of Political Economy 99, 1166–1187.

Burbidge, J., Harrison, A., 1985. (Innovation) Accounting for the impact of fluctuations in U.S. variables on the Canadian economy. Canadian Journal of Economics 18, 784–798.

Cantor, R., Mark, N.C., 1988. The international transmission of real business cycles. International Economic Review 29, 493–507.

Cardia, E., 1991. The dynamics of a small–open economy in response to monetary, fiscal and productivity shocks. Journal of Monetary Economics 28, 411–434.

Domowitz, I.R., Hubbard, G., Petersen, B., 1988. Market structure and cyclical fluctuations in U.S. manufacturing. The Review of Economics and Statistics 70, 55–66.

Epstein, L., 1983. Stationary cardinal utility and optimal growth under uncertainty. Journal of Economic Theory 31, 133–152.

Epstein, L., 1987. A simple dynamic general equilibrium model. Journal of Economic Theory 41, 68–95.

Farmer, R.E.A., Guo, J.T., 1994. Real business cycles and the animal spirits hypothesis. Journal of Economic Theory 63, 42–72.

Finn, M.G., 1990. On savings and investment dynamics in a small–open economy. Journal of International Economics 29, 1–21.

Galí, J., 1994. Monopolistic competition, business cycles and the composition of aggregate demand. Journal of Economic Theory 63, 73–96.

Greenwood, J., Rogerson, R., Wright, R., 1994. Household production in real business cycle theory. In: Thomas Cooley (Ed.), Frontiers of Business Cycle Research, Princeton University Press, Princeton, NJ, pp. 157–174.

Hall, R., 1988. The relation between price and marginal cost in US industry. Journal of Political Economy 96, 921–948.

Head, A.C., World Business Cycles with National and International Returns to Scale, unpublished manuscript, Queens University, 1994.

Hornstein, A., 1993. Monopolistic competition, increasing returns to scale and the importance of productivity changes. Journal of Monetary Economics 31, 299–316.

Johnson, D.R., Schembri, L., 1990. Atheoretical and structural approaches to modeling Canadian–American macroeconomic interaction. Empirical Economics 15, 367–382.

King, R.G., Plosser, C., Rebelo, S., 1988. Production, growth and business cycles: I. The basic neoclassical model. Journal of Monetary Economics 21, 195–232.

Kollmann, R., 1990. Incomplete asset markets and the international business cycle. Manuscript, The University of Chicago, forthcoming Journal of Economic Dynamics and Control.

Kollmann, R., 1993, Fiscal policy, technology shocks and the U.S. trade balance deficit. Manuscript, Economics Department Working Paper No. 9313, The University of Montreal.

Mendoza, E., 1991. Real business cycles in a small–open economy. American Economic Review 81, 797–818.
Morrison, C. Market power, economic profitability and productivity growth measurement: an integrated structural approach. National Bureau of Economic Research, Cambridge, MA, Working Paper No. 3355, May 1990.
Obstfeld, M., 1981. Macroeconomic policy, exchange-rate dynamics, and optimal asset accumulation. Journal of Political Economy 89, 1142–1161.
Obstfeld, M., 1990. Intertemporal dependence, impatience, and dynamics. Journal of Monetary Economics 26, 45–75.
Rotemberg, J., Woodford, M., 1992. Oligopolistic pricing and the effects of aggregate demand on economic activity. Journal of Political Economy 100, 1153–1207.
Rotemberg, J., Woodford, M., 1994. Dynamic general equilibrium models with imperfectly competitive product markets. In: Thomas Cooley (Ed.), Frontiers of Business Cycle Research. Princeton University Press, Princeton, NJ, pp. 243–293.
Rudebusch, G.D., 1993. The uncertain unit root in GNP. American Economic Review 83, 264–272.
Schmitt–Grohé, S., 1995. The international transmission of economic fluctuations: effects of U.S. business cycles on the Canadian economy, finance and economics. Discussion Series Paper 95–6, Board of Governors of the Federal Reserve System, Washington D.C.
Stockman, A.C., Tesar, L.L., 1995. Tastes and technology in a two-country model of the business cycle: explaining international comovements. American Economic Review 85, 168–185.
Uribe, M., 1997. Exchange rate based inflation stabilization: the initial real effects of credible plans. Journal of Monetary Economics 39, 197–221.
Uzawa, H., 1968. Time preference, the consumption function and optimum asset holdings. In: Wolfe, J.N. (Ed.), Value, Capital and Growth: Papers in Honor of Sir John Hicks. The University of Edinburgh Press, Edinburgh, pp. 485–504.