Working Paper 97-16 / Document de travail 97-16

Canadian Policy Analysis Model: CPAM

by

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Bank of Canada 🏛 Banque du Canada

Bank of Canada Working Paper 97-16

June 1997

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Acknowledgments

Abstract

This paper documents the structure and properties of the Canadian Policy Analysis Model (CPAM). CPAM is designed to provide a reasonably complete representation of the Canadian macro economy. It is a one-domestic-good, small-open-economy model, which features an endogenous supply side, behavioural equations for the principal components of demand, forward-looking expectations, and reaction functions for both the monetary and fiscal authorities. The model has an explicit steady state and is dynamically stable over a wide range of disturbances. CPAM is similar in many ways to the Bank of Canada's Quarterly Projection Model (QPM), and it has been calibrated to reflect QPM's dynamic properties in deterministic simulations. CPAM is smaller, however, and has been configured to simulate much faster than QPM so that stochastic simulations on a large scale are feasible.

Résumé

Les auteurs exposent la structure et les propriétés du Modèle d'analyse des politiques (MAP), qui a été conçu pour représenter assez fidèlement l'ensemble de l'économie canadienne. Le modèle décrit une petite économie ouverte qui ne produit qu'un seul bien et où l'offre est endogène et les attentes prospectives. Il comporte des équations formalisant le comportement des principales composantes de la demande ainsi que des fonctions de réaction propres aux autorités monétaires et budgétaires. Il englobe un régime permanent explicite, et sa structure dynamique est stable pour un large éventail de chocs. Le MAP ressemble à de nombreux égards au Modèle trimestriel de prévision (MTP) de la Banque du Canada, et son étalonnage reflète les propriétés dynamiques affichées par le MTP dans le cadre de simulations déterministes. Le MAP est toutefois plus petit et, comme il se résoud bien plus rapidement que le MTP, il permet des simulations stochastiques à grande échelle.

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1.   Introduction

This paper documents the structure and properties of a model designed for stochastic simulation analysis of the Canadian economy and, in particular, issues facing the monetary authority in implementing a nominal anchor for the economy. This model, dubbed CPAM, for Canadian Policy Analysis Model, is based on a family of models developed by QED SOLUTIONS.[1]

CPAM, which has quarterly frequency, is designed to provide a reasonably complete representation of the Canadian macro economy. It is a one-domestic-good, small-open-economy model, which features an endogenous supply side, behavioural equations for the principal components of demand, forward-looking expectations, and reaction functions for both the monetary and fiscal authorities. The model has an explicit steady state and is dynamically stable over a wide range of disturbances. CPAM has about 140 equations, of which perhaps 30 describe the essential agent behaviour. It has many features similar to the Bank of Canada's Quarterly Projection Model (QPM), including the same core theory of household behaviour, and it has been calibrated to reflect current Bank of Canada staff judgments regarding exogenous variables, the numerical steady-state solution, and many features of dynamic properties in deterministic simulations.[2] CPAM is smaller, however, and has been configured to simulate much faster than QPM so that stochastic simulations on a large scale are feasible.[3] Indeed, it was this desire to make stochastic simulations a practical tool for policy analysis that provided the central motivation for building CAPM. See Black, Macklem, and Rose (1997) for a first application of stochastic simulations with CPAM to consider alternative monetary-policy reaction functions for price stability.

There are three domestic sectors: households, firms, and a consolidated government. There is no formal financial sector. Households own capital directly; they also hold the bonds issued by the government and (reflecting the Canadian case) they have liabilities to foreigners. The steady

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1.   CPAM was prepared for the Bank of Canada under a research contract with David Rose of QED SOLUTIONS. CPAM exploits some of the structure and methodology developed in the construction of a model of the New Zealand economy for the Reserve Bank of New Zealand. A Reserve Bank publication on the new Forecasting and Policy System (FPS) is forthcoming.
2.   For details on the structure and properties of QPM see Black, Laxton, Rose, and Tetlow (1994) and Coletti, Hunt, Rose, and Tetlow (1996). An overview is available in Poloz, Rose, and Tetlow (1994).
3.   The difference in simulation times is at least a factor of 5.

state describes an equilibrium of a small open economy with stable ratios of each of these stocks to output.

Fiscal policy is characterized as choices about the debt-to-output and expenditure-to-output ratios; the rate of personal direct taxation is used as the instrument for fiscal closure (respecting the intertemporal budget constraint). Monetary policy is characterized as the choice of a target rate of inflation. This is implemented through a forward-looking reaction function, in which the monetary authority acts on the short-term interest rate according to where inflation is predicted to be, relative to the target rate, 7 to 8 quarters ahead.

There are some differences between CPAM and QPM. An important difference concerns the accounting and modelling structure for prices. QPM abandons the logic of the one-domestic-good paradigm to permit an independent Phillips curve for the CPI excluding food and energy. CPAM sticks more closely to the internal logic of the one-good paradigm. A core domestic price, the domestic aborption deflator at factor cost, PDFC, is treated as both the numeraire for the accounts and the fundamentally stochastic domestic price.[4] We choose PDFC as the core price, since it represents the average revenue received by firms on final sales into the domestic market, which is as close as we can get to a quintessentially domestic price. It is also the price that is most closely linked, in principle, to domestic costs.

All other price indexes are built from this core price and trade prices. Thus, for example, the consumption good price in the model comes from a weighted combination of the import price and the domestic core price for consumption goods, all appropriately adjusted for taxes, using the model's accounting identity structure. In particular, the endogenous share of imported consumption goods provides the weight for the import price in the index.

The Phillips curve in CPAM relates core inflation to domestic demand conditions and some other dynamic factors. But the monetary authority is concerned with the outcome for consumer price inflation. This means that the effect of monetary intervention on import prices through the exchange rate plays an important role in the transmission mechanism and in inflation dynamics generally.

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4. The domestic absorption deflator is defined as follows: Domestic absorption is simply what is produced and not exported: $YD = Y-X$. The absorption deflator is then given implicitly from $PY*Y=PD*YD+PX*X$. This is at market. To get the measure at factor cost, we must remove the direct effect of indirect taxes: $PD*YD=PDFC*YD+$indirect taxes.

Another important difference between CPAM and QPM is in the modelling of dynamics. QPM expresses many adjustment processes using error-correction mechanisms based on the gap between the current value and the steady-state value of a variable. In many cases, however, especially in those shocks where the initial adjustment must be contrary to the steady-state effect, as in most cases where there is a change in the net foreign asset (*NFA*) position, QPM is forced to rely on other special terms to generate the appropriate short-term response. In CPAM, we exploit the underlying theory to a greater degree, building into what we call the "equilibrium" values of the endogenous variables this important distinction between the equilibrium transition path and the full steady-state effects. Thus, CPAM dynamics have an extra layer not developed in QPM. Much of what QPM represents as pure disequilibrium effects, appears in CPAM as "equilibrium dynamics." This enables us to make a much clearer distinction as to why "perverse" short-term movements often arise in scenarios with asset adjustment as a central feature.

Some differences between CPAM and QPM are more style than substance. For example, CPAM is written using Euler equations rather than QPM's explicit solutions in terms of expected future values. An advantage of the CPAM representation is that the equations are much more compact and easier to report. Indeed, *all* of the equations of CPAM are presented and described in this document. The model itself is also more compact, because explicit equations for all the future leads within the expectations structures are not required.[5]

The rest of the paper is organized as follows. In Section 2, we document the complete structure of CPAM. The model equations are reported using TROLL syntax, exactly as they appear in the simulation code. Appendix B provides extra details, including a complete list of all model mnemonics and definitions, the parameter values, the exogenous variable assumptions, and the other inputs into the steady-state solution, as well as that steady-state solution itself. Section 3 describes CPAM's dynamic properties through the results of deterministic simulations of the model's response to a number of standard shocks.

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5.   This means that CPAM does not need the macro for generating expectations that is relied on heavily in QPM. The same thing is achieved within TROLL in the stacking procedure used in the simulation algorithm. Armstrong, Black, Laxton, and Rose (1995) discuss this method.

2.   The structure of CPAM

We now turn to a detailed review of the equations of CPAM. We first review a few points of notation, TROLL syntax, and our measurement conventions, which are necessary background to understanding what follows. We then describe the model equations. The discussion is broken into sections in a relatively standard way, but with a few minor exceptions, the whole system is simultaneous.

2.1   Notation and measurement conventions

Variables with a suffix *.eq* are dynamic equilibrium values. The equilibrium values will converge on steady-state (SS) values. However, the *.eq* values differ, in principle, from the SS values when the model is shocked. Only in special cases will these equilibrium values be identical to the steady-state values in the immediate aftermath of a shock. CPAM exploits this information in modelling the dynamics.

All real variables in CPAM are measured relative to a trend that grows at the SS growth rate of output. In the control solution, the level of output has also been normalized to 1 (annual rates) in some notional base period. Thus, for example, all the annual rate GDP components are fractions—shares of output—in the control solution. Nominal variables are also divided by the domestic absorption deflator, measured at factor cost. In other words, every price in the core model is a relative price. Also, for the steady state, no trends are permitted in shares or relative prices, so all variables have particular numerical solutions. The SS numbers are computed from a solution of the model with leads and lags eliminated. The ease of this procedure is one advantage of writing the model in detrended form. Trend real and nominal growth are reintroduced in a separate component (a TROLL macro we call "postcom") that converts the core model variables to more familiar units.

The core model is written with all variables in their natural quarterly units. Thus, for example, all expenditure flows are at quarterly rates. Similarly, all growth rates, inflation rates, and interest rates are measured quarterly at quarterly rates. Under these conventions, model equations are almost void of code that merely converts units. For studying model output, however, annual rates are often more convenient. The postcom macro provides all the necessary transforms. A variable with prefix *a*, with underscore, as in *a_x,* is the annualized version of the variable *x.* In the case of flows, this is just multiplying by 4. In the case of rates etc., the calculation includes the effect of compounding. Thus, for example, the quarterly-at-annual-rate measure of inflation, *a_pdot,* is

derived from $(1+a\_pdot) = (1+pdot)**4$. Another feature is level transforms. When growth and inflation are added to the model solution, variables with prefix *l_* are created, where appropriate. Thus, one can see the solution for the level of the GDP deflator in the variable *l_py*.

As indicated above, the equations are reported in TROLL format. In TROLL syntax, *x(J)* is the *J*th lead of *x*, and for an endogenous variable in a deterministic simulation this will be the model solution *J* periods ahead. Similarly, *x(-J)* is the *J*th lag of *x*. CPAM uses very few functions or other special operators. Where necessary, these are described with the equation.

The only other feature of TROLL syntax that is necessary for what follows is the labelling convention for equations. Each equation begins with a label, followed by a colon. Then comes the actual equation. It should go without saying, but just to be safe we will say it, labels are arbitrary in a simultaneous system. The entire *N* equations of a non-singular system determine *N* unknowns. Yet some economists persist in wanting to label everything as if this were not true and the model could be considered as a set of reduced-form equations. We use the phrase "proximately determine" when describing some equations to identify the variable that has conventionally been used as the notional "dependent" variable in such discussions, based on recursive solution methods, like Gauss-Seidel. In TROLL, it is the endogenous variable list that matters. Derivatives are taken for all equations with respect to all endogenous variables. Equations do not have to be written in a form already normalized on a particular variable. In fact, the label can be a variable that does not appear in the equation; there are several examples in CPAM. The labels are not actually used for anything real. Hence, they do not even have to be variable names. Of course, it is still necessary to have *N* equations to solve for *N* unknowns, and there is nothing wrong with using the names of the endogenous variables as labels—there are just the right number, after all. Essentially, that is what we have done.

2.2   Growth accounting assumptions

Trend population growth, *ndot,* and trend productivity growth, *qdot,* which is measured in labour units, are exogenous. In this version of the model, there are no variations in these trend values through time. Actual productivity growth, measured as the percentage change in the level of total factor productivity, say, *will* vary with the cycle. Overall trend real growth, *ydot*, is defined from the components, as required by the underlying neoclassical growth model:

(1)   *ydot:*   *ydot* $= (1+ndot)*(1+qdot) - 1.$

Again, this is a trend growth concept and is essentially exogenous. It is *not* the growth rate in actual output period-by-period. That, of course, is endogenous to the model. The numerical assumptions for steady-state growth are taken from QPM (labour-embodied technical progress at 1.3 per cent per annum and population growth at just under 0.95 per cent per annum, for a trend growth in potential output of about 2.25 per cent per annum).

2.3   Expenditure accounts

The standard expenditure add-up identities are included, but with two twists, as alluded to previously. The first is our detrending procedure. Thus model variable *y* is not constant-dollar output. If *Y* is the constant-dollar measure at annual rates, it is rescaled according to *y(t)=Y(t)/ (4*Y0*(1+ydot)**t),* where *Y0* is the annual-rate value in a base period (i.e., we also normalize the control annual-rate value of *y* to be 1 and the quarterly rate value to be 0.25). The same rescaling is carried out for *c, i,* etc. Thus, the control levels of components of spending are their proportional shares of output.

The second twist is that the prices are not the national accounts deflators. Rather, all prices are measured relative to the numeraire price, which we take to be the domestic absorption deflator at factor cost (PDFC). Indirect taxes are levied on consumption, investment, and government goods, at effective rates taken from QPM.

As in QPM, the sectoral accounting framework is simplified. In particular, residential investment and changes in the stock of inventories are notionally included in model "consumption."

2.3.1   The GDP identities

In current terms, we have:[6]

(2)   *y:* $y = c + i + g + x - m,$

(3)   *py:* $py*y = pc*c + pk*i + pg*g + px*x - pm*m.$

In *.eq* terms we have:

(4)   *py.eq:* $y.eq = c.eq + i.eq + g.eq + x.eq - m.eq.$

Note that this is an example of an equation with a label given by a variable that does not appear in the equation itself. We think of *y.eq* as being proximately determined by the supply side of the

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6.   We use the seemingly inconsistent mnemonic *pk* for the flow investment price simply because one of the software packages we use for applications reserves the mnemonic *pi* for the mathematical constant.

model. This equilibrium condition, which imposes the requirement that supply must equal demand, then proximately determines the equilibrium price.

Next comes the identity for the average price at factor cost:

(5)   *pfc:* $py*y = pfc*y + tic*pc*c/(1+tic)$

$+tii*pk*i/(1+tii) +tig*pg*g/(1+tig),$

where *tic, tii,* and *tig* are the rates of indirect tax on consumption, investment, and government purchases, all measured net of any subsidies. The terms involving these variables together reflect net indirect tax revenues. We have the same structure in *.eq* terms:

(6)   *pfc.eq:* $py.eq*y.eq = pfc.eq*y.eq + tic*pc.eq*c.eq/(1+tic)$

$+ tii*pk.eq*i.eq/(1+tii) +tig*pg.eq*g.eq/(1+tig),$

The final equation in this block is a check that the equilibrium model satisfies the GDP identity. Note that, for reasons we explain later, the variable *check1,* which must be identically zero if the identity holds, appears later in the model—in the risk income equation. But it can be thought of as the balancing entry for this identity.

(7)   *check1:* $py.eq*y.eq = pc.eq*c.eq + pk.eq*i.eq + pg.eq*g.eq$

$+ px.eq*x.eq - pm.eq*m.eq.$

2.4   Consumption

There are two kinds of consumers in CPAM. There are forward-looking agents, who make decisions with a view to picking the best path for current and future consumption. Their choices are shown in variables with "fl" in the mnemonic. Thus *cfl* is consumption by forward-looking agents. CPAM also has agents who consume by the simple "rule of thumb" (rt) that they consume what they receive in income every period. Thus, all assets are held by the forward-looking agents. Total consumption, *c,* is the sum of the demands from the two types of agent.

(8)   *c:* $c = crt + cfl.$

Section 2.8.2 describes how disposable income is divided between the two types of agents.

2.4.1 Adjustment dynamics

RT consumers just use up their real disposable income, *ydrt.* Note that the left side is *not* a current dollar expression; *pc* is a relative price (the consumption price divided by PDFC). Thus *pc* here simply converts the real units to be consistent.

(9)   *crt:* $pc*crt = ydrt.$

The next equation contains the consumption dynamics for the forward-looking agents. The structure of the equation is typical of those in the rest of the model. It says that consumption (of forward-looking agents), *cfl,* will converge on its equilibrium value, *cfl.eq,* subject to an adjustment structure, provided through the variable *cfladj,* as well as to the influence of a number of special disequilibrium effects.

(10)   *cfl:* $cfl = cfl.eq + cv1*(ydfl(-2)/pc(-2)-ydfl.eq(-2)/pc.eq(-2))$
$- cv2*(rsl(-2)-rsl.eq(-2))*cfl.eq(-2)$
$+ cv3*(nfa/pc - nfa.eq/pc.eq)$
$- cfladj + cshk.$

The *.eq* variable comes from the core theory, described below. The adjustment code, which replaces *cfladj,* is added by a TROLL procedure that automatically overlays the equation with a polynomial adjustment cost (PAC) structure of order specified in the procedure call. This uses a version of the approach described in Pesaran (1991) and, particularly, in Tinsley (1993). In general, we use a 4th-order adjustment system in CPAM. The adjustment model is documented in Appendix A. However, what it does is add leads and lags of the specified order, all of which act to delay adjustment to the *.eq* values. The TROLL code for the adjustment procedure(s) is available on request.[7]

For FL consumption dynamics, three special disequilibrium terms are included. First, there is an income effect for FL consumers, making them a little bit like RT consumers in responding more to income cycles than the pure *c.eq* theory and PAC dynamics would suggest. Second, as in QPM, there is a direct mechanism for the transmission of monetary policy to consumption demand. The model's policy framework is similar to QPM's; *rsl* is the slope of the term structure.[8] Third,

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7.   There are, in fact, two different adjustment procedures used in CPAM, one for the capital stock dynamics, the other for the rest of the equations. See Appendix A for details.
8.   See Section 2.13 for discussion of this point.

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we have one of the mechanisms needed to make the pure theory usable in practice, a direct effect making consumption respond to the *NFA* gap, as in QPM, to speed the adjustment in cases where asset equilibrium is disturbed.

The variable *cshk* is used to incorporate disturbances (shocks) to consumer spending.

2.4.2 *Equilibrium consumption and wealth*

Total equilibrium consumption is given by the sum of the *.eq* values of the two components, with the RT variable defined precisely as above, but using the *.eq* price and the *.eq* disposable income.

(11)   *c.eq:*   *c.eq = cfl.eq + crt.eq,*

(12)   *crt.eq*:   *pc.eq*crt.eq = ydrt.eq.*

The equilibrium analysis for forward-looking consumers is based on Blanchard (1985) and Weil (1989), but in a discrete-time format, as in Frenkel and Razin (1992) and Black, Laxton, Rose, and Tetlow (1994). The variables have obvious names: *tw* is total wealth, *hw* is human wealth, *fa* is financial assets, *mpcw* is the marginal propensity to consume out of wealth. Note that extra discounting is added in two ways. First, we modify the definition of *cfl.eq* so that it only has the standard form (consumption proportional to wealth) when assets are in steady-state equilibrium. If *fa.eq*, the temporary equilibrium level of financial assets, is above its steady-state level, we make the *.eq* notion of consumption higher than it would otherwise be. This speeds convergence to the steady state. Second, in the definition of human wealth, we use a consumers' discount rate, *rcon.eq,*

which is above the risk-free base rate. *Gamma* here is the probability of death, and *sigma* is the coefficient of intertemporal substitution.

(13)   *cfl.eq: pc.eq*cfl.eq   = mpcw.eq * twfl.eq + zeta*(fa.eq-fa.ss),*

(14) *mpcw.eq: 1/mpcw.eq = (1-gamma)*delta**sigma*(pc.eq/*

pc.eq(+1)*(1+rcon.eq))**(sigma-1)/mpcw.eq(1) + 1,

(15)   *twfl.eq: twfl.eq = hwfl.eq + (1+rcon.eq(-1))*fa.eq(-1)/(1+ydot),*

(16)   *hwfl.eq: hwfl.eq   =ydfl.eq + risk.eq +(1-gamma)*(1+qdot)*hwfl.eq(1)/*

(1+rcon.eq(1)),

(17)   *fa.eq: fa.eq   =ydfl.eq + risk.eq + (1+rcon.eq(-1))*fa.eq(-1)/(1+ydot) -*

pc.eq*cfl.eq,

(18)   *fa.ss: fa.ss   =fa.ss(1).*

The *fa.ss* equation is just a trick to get the current SS solution for the *fa.eq* gap.[9]

One small point that might need elaboration is the role of the *(1+ydot)* deflator for a lagged stock (in the *fa.eq* equation, for example). These things appear in all cumulation equations in CPAM and sometimes in other equations with lags or leads. The adjustment is necessitated by the detrending transform. The core solution for *fa.ss* is a constant. In a converged solution, *fa.eq* will also be at this same value. In accumulation equations, therefore, the lagged stock must be deflated by the gross growth rate to keep the units consistent.

Note that, since all assets are held by forward-looking consumers, we allocate all "risk" income to them in the wealth accounting.

2.5   Investment

We choose to have investment represented by the perpetual inventory (PI) identities. The behaviour of firms is written into the equations that determine stock levels. This is not substantive; these equations could be considered as *k* equations and vice-versa. (The behavioural *k* equations could even be substituted into the PI equations and solved for *i.)* We prefer writing it this way to

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9.   Note that this equation effectively states that *fa.ss* is tied to a terminal condition that, in turn, comes from the steady-state model.

highlight the fact that in a model where stock equilibrium considerations are central, flows adjust to establish and to maintain the desired stock levels. It is not the other way round.

(19)   *i:* $k = (1\text{-}depr)*k(\text{-}1)/(1+ydot) + i,$

(20)   *i.eq:* $k.eq = (1\text{-}depr)*k.eq(\text{-}1)/(1+ydot) + i.eq.$

2.6 Government expenditure and transfers

In CPAM, the consolidated government sector provides a demand for goods and services and also transfers resources to households. The ratio of government spending, *g,* to output, *y,* written as *g_y.eq,* is treated as an exogenous policy choice, as is the level of transfers, relative to output, *gtr_y.eq.*[10]

(21)   *g:* $g = g1*g(\text{-}1) + (1\text{-}g1)*g.eq,$

(22)   *g.eq:* $g.eq = g2*g.eq(\text{-}1) + (1\text{-}g2)*g\_y.eq*y.eq,$

(23)   *gtr:* $gtr = gtr1*gtr(\text{-}1) + (1\text{-}gtr1)*gtr.eq,$

(24)   *gtr.eq:* $gtr.eq = gtr2*gtr.eq(\text{-}1) + (1\text{-}gtr2)*gtr\_y.eq*y.eq.$

This version of CPAM has simple first-order adjustment towards the *.eq* values in these equations. For most temporary shocks, where the *.eq* values are not affected, the government variables will not move at all, if the starting point is an equilibrium. Where, however, the *.eq* value of output does change endogenously in the shock, these equations will add extra dynamics coming from fiscal adjustment. If a user prefers fully exogenous fiscal variables, these equations must be overridden.

2.7 External trade

2.7.1 *Imports*

Like QPM, CPAM is configured under the assumption that imports are driven by end-use component demands. Thus, we break imports down into four parts, one for each component of

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10.   CPAM differs from QPM in accounting explicitly for transfers to households. As a result, CPAM's residual personal income tax rate is more realistic than QPM's.

domestic demand *(cm, im,* and *gm)* and one for those imports that go directly into exports, *xm.* There are current value and *.eq* add-ups.

(25) *m:* $m = cm + im + gm + xm,$

(26) *m.eq:* $m.eq = cm.eq + im.eq + gm.eq + xm.eq.$

Each component of imports is, in turn, written as a penetration ratio times the level of the total component demand. Thus, for example, imports for consumption are given by the product of the consumption import penetration ratio, written as *cm_c*, and the level of consumption demand. There are current-value and *.eq*-value versions of each of these identities. The main import penetration ratios are endogenous (the exception is the re-export component, which we simply hold at a fixed share of exports). The equilibrium values are made functions of the appropriate relative price of the home-source to the foreign-source good. Thus, for example, *cm_c.eq* responds (negatively) to the ratio *pcm.eq/pcd.eq,* which is the domestic price of imported consumption goods relative to the domestic price for consumption goods.

We will show below that the law of one price is made to hold on the margin, so that *pcm.eq* can be considered to be the foreign price times the *.eq* real exchange rate. Hence, a permanent real depreciation or a permanent shock to the foreign consumption good price will lower the proportion of *c* that comes from abroad. The actual current ratios, for example *cm_c,* are determined by standard CPAM adjustment equations. Thus, the pass-through of a permanent foreign price shock or an exchange rate shock into domestic-currency import prices is not instantaneous. Note that we also allow for separate dynamic effects of the exchange rate within the adjustment equations, using the same relative price. This term will capture the effects of temporary shocks to the exchange rate or foreign prices, where the *.eq* values are unchanged.

(27) *cm:* $cm = cm\_c*c,$

(28) *cm.eq:* $cm.eq = cm\_c.eq*c.eq,$

(29) *cm_c.eq:* $cm\_c.eq = cm\_c0 - cms2*pcm.eq/pcd.eq,$

(30) *cm_c:* $cm\_c = cm\_c.eq - cmv1*(pcm(-1)/pcd(-1)$
$-pcm.eq(-1)/pcd.eq(-1)) - cm\_cadj,$

(31)   *im:* $im = im\_i*i,$

(32)   *im.eq:* $m.eq = im\_i.eq*i.eq,$

(33)   *im_i:* $im\_i = im\_i.eq - imv1*(pkm(-1)/pkd(-1)$
                            $- pkm.eq(-1)/pkd.eq(-1)) - im\_iadj,$

(34) *im_i.eq:* $im\_i.eq = im\_i0 - ims2*pkm.eq/pkd.eq,$

(35)   *gm:* $gm = gm\_g*g,$

(36)   *gm.eq:* $gm.eq = gm\_g.eq*g.eq,$

(37)   *gm_g:* $gm\_g = gm\_g.eq - gmv1*(pgm(-1)/pgd(-1)$
                            $-pgm.eq(-1)/pgd.eq(-1)) - gm\_gadj,$

(38) *gm_g.eq:* $gm\_g.eq = gm\_g0 - gms2*pgm.eq/pgd.eq,$

(39)   *xm:* $xm = xm\_x*x,$

(40)   *xm.eq:* $xm.eq = xm\_x.eq*x.eq,$

(41)   *xm_x:* $xm\_x = xm\_x.eq.$

2.7.2   Exports

For exports, the equilibrium level, relative to output, is made a function of the domestic-currency price of exports. This price, like all prices in the core of CPAM, is written relative to the numeraire price, PDFC. It thus already expresses the relevant margin for producers—what they can get abroad relative to what they can get at home by selling into the domestic market.

In this version of CPAM, the *.eq* export price is given by the world price multiplied by the *.eq* price of foreign exchange. A permanent real depreciation will raise the ratio of exports to output, all else equal, as will a permanent increase in the world price for the domestic export good (which must be interpreted as a form of shock to the terms of trade, not as a general foreign price shock). Adjustment is then specified in the usual way, again with a term to allow for effects from temporary shocks.

In the calibration of equations like the one for *x.eq,* the base level of the ratio, *x_y0,* is set to reflect the data. This can include any historical or predicted future trends that are judged to be exogenous to the macro cycle.

(42)   *x.eq:* $x.eq/y.eq = x\_y0 + x2*px.eq,$

(43)   *x:* $x = x.eq + xv1*(px(-2)-px.eq(-2))*x.eq(-2) - xadj.$

2.7.3   Trade balance identities

Finally, we have the identities for the trade balance.

(44)   *netx:* $netx = px*x - pm*m,$

(45) *netx.eq:* $netx.eq = px.eq*x.eq - pm.eq*m.eq.$

2.8   Income accounts

2.8.1   Wages

The equilibrium real wage, *w.eq,* is given by the standard marginal product condition. The only thing at all unusual here is that *w.eq* is measured in the units of domestic absorption (i.e., the money wage is implicitly deflated by PDFC, like all nominal levels). This explains the presence of *pfc* in the equation; it converts the units to factor cost as required by the marginal product condition. The parameter *alpha* is the exponent on capital in the CRS, Cobb-Douglas production function. The equilibrium unemployment rate, *u.eq,* is exogenous (more on this below).

(46)   *w.eq:* $w.eq = (1-alpha)*pfc.eq*y.eq/(1-u.eq).$

The market real wage is determined by a standard CPAM adjustment equation. A term in the unemployment rate gap is added to the dynamics to allow for any direct cyclical properties of the real wage.

(47)   *w:* $w = w.eq - wv1*(u-u.eq) + wv2*(pfc(-1)-pfc.eq(-1))$
                                       $+ wv3*(tfp(-1)-tfp.eq(-1)) - wadj + wshk.$

We also include the explicit transforms to give the real wage to the producer, *wp*, and to the consumer, *wc*. Since both *w* and *pfc* are divided by the absorption deflator at factor cost, *wp* is equal to the nominal wage divided by the output deflator at factor cost, which is the real cost of labour to the firm. Similarly, *wc* is equal to the nominal wage divided by the consumption deflator, as the

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rescaling of both numerator and denominator by PDFC cancels. Neither *wc* nor *wp* is used explicitly in this version of the model; these variables are included for information only.

(48)   *wp.eq:* $wp.eq = w.eq/pfc.eq$,

(49)   *wp:* $wp = w/pfc$,

(50)   *wc.eq:* $wc.eq = w.eq/pc.eq$,

(51)   *wc:* $wc = w/pc$.

2.8.2   Labour income

Total labour income is simply the payments to labour implicit in the above:

(52)   *ylab:* $ylab = w*(1-u)$,

(53)   *ylab.eq:* $ylab.eq = w.eq*(1-u.eq)$.

Labour income is split between rule-of-thumb and forward-looking consumers and transfers are added. (The proportion of RT consumers in the model is represented by the parameter *lamda*.) The portion of transfers that is taxable is given by parameters, *yd1* (for RT consumers) and *yd2* (FL consumers). Labour income plus taxable transfers are taxed at the same rate, *td*, for both types of consumer, giving us the following equations for disposable income:

(54)   *ydrt:* $ydrt = ((1-td)*(ylab+yd1*gtr)+(1-yd1)*gtr)*lamda$,

(55)   *ydrt.eq:* $ydrt.eq = ((1-td.eq)*(ylab.eq+yd1*gtr.eq)+(1-yd1)*gtr.eq)*lamda$

(56)   *ydfl:* $ydfl = ((1-td)*(ylab+yd2*gtr)+(1-yd2)*gtr)*(1-lamda)$,

(57)   *ydfl.eq:* $ydfl.eq = ((1-td.eq)*(ylab.eq+yd2*gtr.eq)+(1-yd2)*gtr.eq)$
                              $*(1-lamda)$.

2.8.3   Risk income

This term measures asset income over and above the level provided by *rcon.eq,* as well as some other miscellaneous items that need to be recorded as income somewhere. See also the discussion of relative rates of return on assets, below.

(58)   *risk.eq:*   *risk.eq = (rk.eq(-1)-rcon.eq(-1))*pk.eq(-1)*k.eq(-1)/(1+ydot)*

+k.eq(-1)*((1+rk.eq(-1))*(pi.eq(-1)-pk.eq(-1))

-(1-depr)*(pi.eq-pk.eq))/(1+ydot)

+(rgb.eq(-1)-rcon.eq(-1))*gb.eq(-1)/(1+ydot)

+(rnfa.eq(-1)-rcon.eq(-1))*nfa.eq(-1)/(1+ydot)+ check1.

Note that the national accounts identity check variable, *check1,* appears here. "Risk" is total household "income," over and above what is notionally paid either through wages or through returns on assets at the rate *rcon.eq* (which is used within the formal model of household choice). Any residual shows in *check1*. We put this term here because there is a small problem of consistency in the first period of a shock that changes equilibrium values—associated with the imprecision of discrete representations of instantaneous effects. The effects of this problem are minimized when we put the check in the *risk.eq* equation, because the small discrepancy that appears tends to cancel an inappropriate blip in *risk.eq* that would otherwise appear.

There are two reasons why *risk.eq* is required to balance the accounts in CPAM. The first is that the core model assumes perfect capital mobility, that is, a single real interest rate, where as the accounting framework allows for different interest rates for capital, government debt, and net foreign assets. Terms in *risk.eq* serve to square this discrepancy by transferring the income from interest payments above that which the core model would imply back to the consumer in a lump-sum manner. See Black, Laxton, Rose, and Tetlow (1994) for more discussion of this technique. The second reason, described more below, is that the adjustment of the capital stock is costly in CPAM. The term *risk.eq* accounts for the costs of adjusting capital in a way that still allows the model's accounting structure to resemble that of the National Accounts.[11]

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11.   Macklem (1993) discusses this problem and incorporates a different solution that *does* imply a deviation from the conventions of the National Accounts.

2.9   Capital stock and user cost of capital

The equation for the stock of capital, *k*, is a standard adjustment equation around the equilibrium level, *k.eq*. This is really an investment equation, written in the stock dimension. The *k.eq* level comes from the firm's optimization problem.

In CPAM, firms chose *k.eq* by maximizing the present value of profits under quadratic adjustment costs. This means that, whenever a firm faces a change, it must balance off altering its capital stock and moving quickly to a more efficient point, with the costs of adjusting capital.

The way this is modelled is with the introduction of the price *pi.eq*.[12] This price, which serves a similar purpose to Tobin's *q*, serves to indicate to the firm when and how quickly it should increase its stock of capital. From (62) it is seen that when investment increases above its steady-state level, *pi.eq* also increases. This, in turn, increases the cost of capital and counteracts the high investment demand.

(59)   *k:* $k = k.eq + kv1*(y(-4)-y.eq(-4))$

$- kv2*(rsl(-4)-rsl.eq(-4))*k.eq(-4) - kadj + kshk,$

(60)   *k.eq:* $cc.eq = alpha*pfc.eq(1)*y.eq(1)*(1+ydot)/k.eq,$

(61)   *cc.eq:* $cc.eq = ((1+rk.eq)*pi.eq - (1-depr)*pi.eq(1)$

$- tk.eq*depr*pk.eq(1))/(1-tk.eq),$

(62)   *pi.eq:* $pi.eq = pk1*pk.eq+(1-pk1)*pk.ss + ke1*(i.eq-i.ss),$

(63)   *i.ss:* $i.ss = i.ss(1),$

(64)   *pk.ss:* $pk.ss = pk.ss(1).$

2.10   The government budget constraint: bonds and taxes

The fundamental fiscal choice in CPAM is the debt/output ratio, *gbtar_y*. Given *y.eq,* this determines a target level of debt, *gbtar*. A structure is specified to handle transition paths; the variable *gb.eq* can be considered as defining a transition target path when *gbtar* changes. The intertemporal government budget constraint, written with *.eq* values, then provides the personal income tax rate, *td.eq,* that would support those fiscal choices, conditional on all other *.eq* values.

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12.   The reader will recall that *pk* is the relative price of investment goods.

The regular government budget constraint determines actual government debt, *gb,* conditional on all other variables, and, in particular, on *td*, the actual current personal income tax rate. The system is reconciled with the fiscal reaction function that sets the actual tax rate. This must achieve two goals. The personal tax rate, *td,* must go to the right level in the end to support the steady state. But it must also generate the necessary dynamic profile to bring debt to the equilibrium or target level. The net indirect tax rates and the profits tax rate are exogenous.

(65)   *gbtar:*   *gbtar = gbtar_y.eq*y.eq,*

(66)   *gb.eq:*   *gb.eq = gb.eq(-1) - td1*(gb.eq-gbtar),*

(67)   *gb:*   *gb + td*(ylab+(yd1*lamda+yd2*(1-lamda))*gtr) + tic*pc*c/(1+tic) +*
                                  tii*pk*i/(1+tii) + tig*pg*g/(1+tig) + tk*(pfc*y - ylab -
                                  depr*pk*k(-1)/(1+ydot))
                                  = (1+rgb(-1))*gb(-1)/(1+ydot) + pg*g + gtr,

(68)   *td.eq:*   *gb.eq + td.eq*(ylab.eq+(yd1*lamda+yd2*(1-lamda))*gtr.eq)*
                                  + ic*pc.eq*c.eq/(1+tic) + tii*pk.eq*i.eq/(1+tii)
                                  + tig*pg.eq*g.eq/(1+tig) + tk.eq*(pfc.eq*y.eq-ylab.eq-
                                  depr*pk.eq*k.eq(-1)/(1+ydot))
                                  = (1+rgb.eq(-1))*gb.eq(-1)/(1+ydot) + pg.eq*g.eq +gtr.eq,

(69)   *td:*   *td = td0*td(-1) + (1-td0)*(td.eq + td3*(gb-gb.eq)).*

2.11   Net foreign assets and the remaining asset identities

Next, we have the *NFA* accumulation identities and the definitions of the asset sums. Note that we label the *fa.eq* equation as determining the level of the real exchange rate. This reflects the fact that the household model pins down a value for *fa.eq.* Given a choice of a debt level by government, and a choice by firms of the equilibrium level of *k*, the *nfa.eq* position is the residual that can be set to satisfy the *fa.eq* decision. Through the *nfa.eq* accumulation equation, we have a level for equilibrium net exports consistent with this choice for *nfa.eq.* In effect, the real exchange

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rate gets determined to support this equilibrium. That may not be immediately clear from the labelling of these equations, but it is a good way to think about it.

(70) *nfa:* $nfa = (1+rnfa(-1))*nfa(-1)/(1+ydot) + netx,$

(71) *nfa.eq:* $nfa.eq = (1+rnfa.eq(-1))*nfa.eq(-1)/(1+ydot) + netx.eq,$

(72) *fa:* $fa = pk*k + gb + nfa,$

(73) *z.eq:* $fa.eq = pk.eq*k.eq + gb.eq + nfa.eq.$

2.12 Supply

2.12.1 Employment

The unemployment rate is proximately determined in a standard adjustment equation. It may be clearer to think of this as an employment equation. Two special cycle variables are used: the output gap to pick up direct links between employment and demand conditions, and a wage gap to pick up relative price effects (movements along the short-run demand function).

(74) *u:* $u = u.eq - uv1*(y-y.eq)+uv2*(w-w.eq) - uadj + ushk.$

2.12.2 Total factor productivity

The production function is imposed to solve for total factor productivity, *tfp,* on a period-by-period basis. This is how demand is satisfied in each period. Note, as well, that *tfp* is normalized in the calibration to set the *y* units to 1, at annual rates, or 0.25 at quarterly rates, and is deflated by $(1+qdot)**t.$

(75) *tfp:* $y = 0.25*tfp*(k(-1)/(1+ydot))**alpha*(1-u)**(1-alpha).$

2.12.3 Equilibrium and potential output

The model uses two different measures of "equilibrium" output. One, *y.eq*, uses *.eq* measures everywhere in evaluating the production function. This measure is used in all the forward-looking real equations. The other, *yp*, is potential output for the purpose of modelling inflation dynamics. It is simply the production function evaluated with actual capital and *.eq* values for everything else. This treats capital as a quasi-fixed factor and employment as a completely variable factor in the short run. It could be interesting to introduce a distinction between the NAIRU

(short-term attainable labour use) and the natural rate (longer-term labour attainable use), but in this version of CPAM no such distinction is made and *u.eq* is the natural rate, which is taken from QPM.

(76)   *y.eq:* $y.eq = 0.25*tfp.eq*(k.eq(-1)/(1+ydot))**alpha$
                         $*(1-u.eq)**(1-alpha),$

(77)   *yp:* $yp = 0.25*tfp.eq*(k(-1)/(1+ydot))**alpha$
                         $*(1-u.eq)**(1-alpha).$

2.13   The monetary nexus

2.13.1 The reaction function

The monetary authority in CPAM has a long-run target for the inflation rate, given by *pdottar.* To hit that target, the monetary authority influences an instrument variable, *rn,* which can be thought of as the short-term interest rate. The intermediate target is the slope of the term structure, *rsl.* The reaction function is forward-looking, using leads of 7 to 8 quarters. There is no interest rate "smoothing" term in CPAM.

The central bank is presumed to use consumer price inflation in evaluating the need for action. The variable *pcdot4* is a 4-quarter rate of change. In the core model, it is measured at quarterly rates to be consistent with other units. In the output, its more natural annual-rate cousin appears as *a_pcdot4.*

(78)   *rn:* $rsl = rsl.eq + rsl7*(pcdot4(7)-pdottar(7))$
                         $+ rsl8*(pcdot4(8)-pdottar(8)) + rslshk.$

CPAM follows QPM in specifying the reaction function in terms of the slope of the term structure. There are a number of reasons for this approach. The main point concerns how we identify the transmission mechanism. Historical movements in real interest rates contain more than monetary innovations. Since monetary innovations will tend to have more influence on short rates than long rates, the slope of the term structure provides a better measure of the actions of monetary policy than does any measure of the level of interest rates. The empirical evidence supports this view.[13]

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13. See Côté and Macklem (1996) and Macklem, Paquet, and Phaneuf (1996) for a review of this evidence and
     other arguments for writing a model this way.

2.13.2 The term structure of interest rates

Nominal and real interest rates are linked through Fisher equations, such as:

(79)   r: $1+rn = (1+r)*(1+pdot(1))$,

(80)   rn.eq: $1+rn.eq = (1+r.eq)*(1+pdottar)$.

Here we use model-consistent expectations, and we assume that interest rates are influenced by the core inflation rate, *pdot*, and not by relative price changes, such as would be reflected in differences between consumer price inflation and *pdot*.

CPAM has a simplified version of the term structure of interest rates, relative to the model in QPM. The maximum explicit horizon is limited to five years, half the QPM value, to keep the size of the simulation problem smaller. The basic theory is similar to that in QPM, with the core structure coming from the expectations model of the term structure. The equations are written in a more compact form, however, using an Euler representation. In the mnemonics, we use a tag "5" for a five-year rate. We use a tag "l" for the model's long rate. The term premium, *rt5.eq,* is set to 50 basis points, as in QPM, and assumed to be constant in the database. The equations, however, allow for the possibility of a time-varying premium.

(81)   rn5.eq: $1+rn5.eq = (1+rn5.eq(1)) * ((1+rt5.eq)/(1+rt5.eq(1))) *((1+rn.eq)/$
$(1+rn.eq(20)))**(1/20)$,

(82)   rn5: $1+rn5 = (1+rn5(1)) * ((1+rt5.eq)/(1+rt5.eq(1)))$
$*((1+rn)/(1+rn(20)))**(1/20)$,

(83)   rnl.eq: $rnl.eq = rn5.eq$,

(84)   rnl: $1+rnl = rl1*(1+rn)*(1+rt5.eq) + rl2*(1+rn5) + (1-rl1-rl2)*(1+rnl.eq)$,

(85)   r5.eq: $1+r5.eq = (1+r5.eq(1)) * ((1+rt5.eq)/(1+rt5.eq(1))) *((1+r.eq)/$
$(1+r.eq(20)))**(1/20)$,

(86)   r5: $1+r5 = (1+r5(1)) * ((1+rt5.eq)/(1+rt5.eq(1)))$
$*((1+r)/(1+r(20)))**(1/20)$,

(87)   rl.eq: $rl.eq = r5.eq$,

(88)   *rl:* $1+rl = rl1*(1+r)*(1+rt5.eq) + rl2*(1+r5)$

                                    $+ (1-rl1-rl2)*(1+rl.eq),$

(89)   *rsl:* $1+rsl = (1+rn)/(1+rnl),$

(90)   *rsl.eq:* $1+rsl.eq = (1+rn.eq)/(1+rnl.eq).$

2.13.3 Links to world rates and "risk" premia

Real domestic rates of return are linked to world rates. The base (risk-free) real rate, *r.eq,* is linked directly to the world rate, *rrow.eq.* This return is not available on any domestic asset, however. The net return (after depreciation) to capital, *rk.eq,* the return on domestic government bonds, *rgb.eq,* and the return on net foreign assets, *rnfa.eq,* are written as the long rate plus a differential. This we call the "risk" premium. Here, our notation becomes just a trifle ambiguous. For example, *rk_rl.eq* is a difference, not a ratio as elsewhere.

(91)   *r.eq:* $r.eq = rrow.eq,$

(92)   *rk.eq:* $rk.eq = rl.eq + rk\_rl.eq,$

(93)   *rgb:* $rgb = rl + rgb\_rl.eq,$

(94)   *rgb.eq:* $rgb.eq = rl.eq + rgb\_rl.eq,$

(95)   *rnfa:* $rnfa = rl + rnfa\_rl.eq,$

(96)   *rnfa.eq:* $rnfa.eq = rl.eq + rnfa\_rl.eq,$

(97)   *rcon.eq:* $rcon.eq = rl.eq + rcon\_rl.eq.$

Usually, the world real interest rate is simply set at its equilibrium value, but this equation can be used to bring this part of any cyclical effects of foreign shocks into CPAM, if desired.

(98)   *rrow:* $rrow = rrow.eq.$

2.14   Exchange rate dynamics

Next we have the equation for the dynamics of the real exchange rate. It is important to understand that, as in QPM, the equilibrium level of the real exchange rate comes from elsewhere in the model—from the nexus that determines wealth and the equilibrium structure of trade. This discussion is about the dynamics. The key equation is a version of the nominal interest parity condition. However, the exchange rate does not act as a pure jumper variable because we include

some inertia through a lag, and an independent role for the *.eq* value. We also assume that the expected *z, ze*, includes some inertia from a lag and from a weight on the *z.eq* value. In this version of the model, there is no weight on the *.eq* value in the expectations equation.

(99)   *ze:* $ze = zf1*z(1) + zl1*z(-1) + (1-zf1-zl1)*z.eq(1),$

(100)   *z:* $z = z1*z(-1) + z2*ze*(1+rrow)/(1+r) + (1-z1-z2)*z.eq$
                                          $+ zshk.$

2.15   Inflation

2.15.1 The Phillips curve

The CPAM Phillips curve proximately determines inflation for the numeraire price, the domestic absorption deflator at factor cost (PDFC). The logic of CPAM's price sector will be spelled out below, in a description of the entire relative price system. For now, let us just say that each domestic price in CPAM is constructed as a weighted combination of the core domestic price and a foreign price, all appropriately adjusted for any indirect taxes. For example, the GDP deflator, the average output price, is given by a weighted combination of the average domestic price and the export price, with the weight on the latter given by the share of output that is exported. Similarly, all domestic spending is some mix of imports and domestic absorption, and all component prices reflect that combination of import prices and the core domestic price. Since the central bank is presumed to formulate its actions based on the anticipated course of consumer prices, all elements that have an effect on relative consumption prices have a special role in the nominal dynamics. But core inflation remains a concept applied to PDFC.

The model equation for the rate of change of PDFC, which we call *pdot,* is as follows:

(101)   *pdot:* $pdot = pdf1*(pda4*pdotea+(1-pda4)*pcdotea) + pdf2*pdot(1)$
                                  $+ (1-pdf1-pdf2)*(pda1*pdot(-1)+(1-pda1)*pdot(-2))$
                                  $+ pd0*(y(0)-yp(0)) + pd1*(y(-1)-yp(-1))$
                                  $+ pd2*MAX(y(0)-yp(0),0)+pd3*MAX(y(-1)-yp(-1),0)$
                                  $+ pda5*(pm/pm(-1)-1) + pda6*(px/px(-1)-1)$
                                  $- pd4*(pd5*(w.eq-w.eq(-1)) +pd6*(w.eq(-1)-w.eq(-2))$
                                  $+pd7*(w.eq(-2)-w.eq(-3))) + pdotshk.$

The CPAM Phillips curve has many standard features. It imposes the long-run natural-rate hypothesis (i.e., there is no permanent trade-off between output or employment and the rate of inflation). In the short run, however, there is a dynamic link between excess demand, $y - yp$, and inflation, $pdot$.[14] Recent empirical evidence suggests that this linkage is asymmetric, as in the original Phillips (1958) curve. This asymmetry is such that the positive effect of excess demand on inflation is stronger than the negative effect of an equivalent degree of excess supply. For Canada, results documented in Laxton, Rose, and Tetlow (1993) led to this feature being included in QPM. Turner (1995) and Debelle and Laxton (1996) have also found significant asymmetry of this sort for the Canadian data.[15] The form of this function in CPAM is the same as in QPM—a piecewise linear version with a steeper slope when excess demand is positive, as provided by the *MAX* terms in equation (101).

The first part of equation (101) captures intrinsic and expectational dynamics. The structure is based on a contracting paradigm, with periodic bargaining, as in Fuhrer and Moore's (1995a; 1995b) "real wage" version of Taylor's (1980) model. The terms *pdotea* and *pcdotea* are averages of expectations formed in recent quarters when contracts still extant were signed. We assume that there is annual bargaining. Thus, for example,

(102) *pdotea:pdotea = (pdote + pdote(-1) + pdote(-2) + pdote(-3)) / 4,*

where *pdote(-i)* is the expectation that was formed *i* quarters in the past. We describe how expectations are formed in the next subsection. The equation for *pcdotea* has the same form:

(103) *pcdotea: pcdotea   = (pcdote + pcdote(-1) + pcdote(-2) + pcdote(-3)) / 4.*

The presence of both expectations reflects the notional wage bargaining paradigm that lies behind this equation. Firms care about their selling price and the real wage in those terms, while workers

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14. In simulation, the level of potential output, *yp*, in the model comes from evaluating the production function at full employment and trend factor productivity, but with the existing stock of capital. This treats capital as a quasi-fixed factor and employment as completely variable in the short run, as is traditional in such models.

15. This evidence is not limited to the Canadian case. Turner also reports significant asymmetry for the United States and for Japan. Laxton, Meredith, and Rose (1995) find significant asymmetry for a pooled sample of G7 countries. Clark, Laxton, and Rose (1996), Debelle and Laxton (1997), and Clark and Laxton (1997) find significant asymmetry for the United States. Fisher, Mahadeva, and Whitley (1996) find significant asymmetry for the U.K. data, as do Debelle and Laxton. Isard and Laxton (1996) find significant asymmetry for a pooled sample with France, Italy, and the United Kingdom. Bean (1996) reports evidence for modest asymmetry for a panel of OECD countries.

care about consumer prices and the real wage in consumer goods. When relative prices are changing, both parties have some influence on nominal wage dynamics.[16]

Equation (101) also embodies a second level of dynamics in price setting. The bargaining/ expectations structure described above is thought of as reflecting cost pressures, but that is not the only source of inertia. The term *pdot*(1) represents a one-quarter-ahead, model-consistent forecast, and there are also lags of the actual inflation rate—reflecting quarterly price adjustment by firms conditional on the underlying cost trend.

We allow a small direct effect of trade prices on core inflation. We remind the reader that both *pm* and *px* are measured relative to the numeraire price, so these terms are not inflation rates. Rather they are measures of the extent to which changes in these particular prices differ from those in the core price. Adding these effects can be motivated in two ways. First, no price is determined in isolation in a general system. If import prices fall, competition on the margin to retain domestic market share will have an effect on domestic prices. Similarly, if export prices rise, firms have an incentive to switch to export sales from domestic sales, and this will create competitive pressures for domestic prices to follow. The second motivation comes from the cost side. There is no direct measure of cost effects in the equation, but one can think of these terms as capturing any pass-through into costs (wages), and hence prices, from foreign shocks.

The term in the wage gap at the end is designed to capture the role of prices in engineering changes in the *real* wage when the equilibrium for the latter changes. The relative strength of this effect will determine how much of such adjustment comes through prices and how much through changes in the nominal wage. We use this term to calibrate CPAM to have similar properties to QPM for a productivity shock.[17]

2.15.2 Expectations

Inflation expectations are specified using a variant of the Buiter and Miller (1985) mixed model with both forward- and backward-looking components. We also add a small weight on the *perceived* (or expected) target rate of inflation, which we call *pdottare* (more on this below). We

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16. In the larger model from which CPAM is drawn, these ideas are reflected more formally in the equations. For CPAM, we have stripped out the details of the bargaining model as part of the effort to speed simulation times.

17. This is another ad hoc element that replaces aspects of the larger model from which CPAM is drawn.

assume, here, that *pdot* and *pcdot* expectations are formed in the same way. There is no fundamental reason why this has to be so. The equations are as follows:

(104)   *pdote:* $pdote = (1\text{-}pde0\text{-}pde1)^* (pdl1^*pdot(\text{-}1) + (1\text{-}pdl1)^*pdot(\text{-}2))$

$+ pde1^*pdot4(4) + pde0^*pdottare,$

(105)   *pcdote:* $pcdote = (1\text{-}pde2\text{-}pde3)^*(pdl1^*pcdot(\text{-}1) + (1\text{-}pdl1)^*pcdot(\text{-}2))$

$+ pde2^*pcdot4(4) + pde3^*pdottare.$

The backward-looking component is a weighted average of the previous two observations of inflation. The forward-looking component is a model-consistent forecast. The term *pdot4* stands for a 4-quarter rate of change; it enters with lead 4, which makes this term the forecast rate of inflation over the next 4 quarters, the assumed bargaining horizon.

The perceived target is formulated as follows:

(106) *pdottare:* $pdottare = ptl1^*pdottare(\text{-}1) + ptl2^*pdottare(\text{-}2) + (1\text{-}ptl1\text{-}ptl2)$

$^*(ptl3^*(pdot4(16)+pdot4(20))/2 + (1\text{-}ptl3)^*pdottar).$

The expected target rate of inflation evolves as a second-order transfer function, with the underlying process driven by a weighted average of the model-consistent forecast for the 4-quarter inflation rate 4 and 5 years ahead (we put 0 weight on the actual target, i.e., *ptl3*=1). This term is used only in the expectations equations, (104) and (105), where it is given a relatively small weight of 0.1. It is designed to represent the effects of credibility. If the monetary authority is expected to keep inflation within a reasonable range of the target level in the medium term, then the expected target will remain very close to the announced target. This will provide something of an anchor to expectations, damping their response to short-term cyclical effects. By contrast, if the monetary authority's reaction function is not expected to keep inflation close to the target, this term will pull expected inflation away from the announced target, even if the recent history is good and the short-run prospects are for inflation to remain close to that target level. This captures the idea that it can take more than a few good outcomes for the monetary authority to gain credibility, and that credibility is fragile and, once lost, is hard to regain.

In a policy shock, where the target is changed, the above equation acts as a learning rule. Agents gradually learn the new target rate. The dominant root in the AR part is about 0.84. Thus, it takes about five years for expectations of the target to converge on the actual new target

(assuming that the monetary authority is doing what is necessary to make the actual outcome conform to that new target).

2.16　Relative prices

The key to CPAM's representation of price dynamics is the identification of a core process for inflation, onto which is built an elaborate system of relative price dynamics that exploits all the available information from the identities that describe the composition of the components of spending.[18]

The core domestic price in CPAM is the domestic absorption deflator at factor cost, PDFC. This is the average revenue received by firms from final sales with domestic end use.[19] Each domestic price can be considered to be a weighted average of the price paid for domestic-source goods and the price paid for imported goods of that type. In each case, moreover, there is an identity that must be respected in this construct; it is not just any weighted average, the weights have to be consistent with the quantities.

Both import and export prices are tied to exogenous world values.[20] However, pass-through is not instantaneous. The *.eq* version has relatively quick pass-through, but we model the actual domestic currency import prices using standard CPAM adjustment equations.

For the three main components of domestic absorption, *c, i,* and *g,* we also allow for variation in the relative domestic absorption price. This is another example of the compromise necessary to give the one-good paradigm of domestic production a chance to match the complexity of the real world. For example, the pricing of domestically produced investment goods has been as profoundly affected by the revolution in computer and communications technology as has world pricing. We need, therefore, to break the strict logic of the supply side that says that there is one output good sold for all purposes. We do this by introducing three domestic price relatives: *pcd*,

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18.　In this, CPAM has a slightly cleaner system for relative price accounting than does QPM, as well as a clearer accounting distinction between domestic and foreign "components" of the inflation process. QPM deliberately violates the logic of the one-domestic-good paradigm to allow an independent equation for the dynamics of the CPI, excluding food and energy. In CPAM, we return to the methodology of SAM (Rose and Selody 1985) and build *all* prices up from their source components.

19.　If the price received for exports is the same, then PDFC is the same as *PFC*, the overall deflator at factor cost. However, that is not the case, in fact, so there is a small wedge between the two measures. It is the overall *PFC* that is relevant to firms in their decisions.

20.　This version of CPAM does not have the almost-small-open-economy feature of QPM.

pkd, and *pgd.*[21] As is the case for all CPAM prices, these are written relative to the numeraire, PDFC. Thus, there is an identity that requires that the appropriately weighted average of these domestic price relatives equal 1. There are two versions of this identity, towards the end of the following list, in the equations labelled for *pcd.eq* and *pcd*. Note also that in the equation immediately above the one for *pcd.eq,* we show the numeraire convention explicitly via the "1" in front of the domestic absorption terms in an identity that provides a second check on whether the *.eq* model has obeyed all the necessary restrictions to satisfy the add-up identity using factor cost measures.

(107)   *pc:* $pc*c = (1+tic)*(pcd*(c-cm) + pcm*cm),$

(108)   *pc.eq:* $pc.eq*c.eq = (1+tic)*(pcd.eq*(c.eq-cm.eq) + pcm.eq*cm.eq),$

(109)   *pcm:* $pcm = pcm.eq + pcmv1*(z-z.eq)*pcrow.eq$
$+ pcmv2*(pcrow-pcrow.eq)*z.eq - pcmadj,$

(110)   pc*m.eq:* $pcm.eq = (1-pcm1)*pcm.eq(-1) + pcm1*pcrow.eq*z.eq,$

(111)   *pk:* $pk*i = (1+tii)*(pkd*(i-im) + pkm*im),$

(112)   *pkm.eq:* $pkm.eq*i.eq = (1+tii)*(pkd.eq*(i.eq-im.eq)+ pkm.eq*im.eq),$

(113)   *pkm:* $pkm = pkm.eq + pkmv1*pkrow.eq*(z-z.eq)$
$+ pkmv2*(pkrow-pkrow.eq)*z.eq - pkmadj,$

(114)   *pkm.eq:* $pkm.eq = (1-pkm1)*pkm.eq(-1) + pkm1*pkrow.eq*z.eq,$

(115)   *pkd:* $pkd = pk.eq + pkdv1*(i/i.eq-1) - pkdadj,$

(116)   *pg:* $pg*g = (1+tig)*(pgd*(g-gm) + pgm*gm),$

(117)   *pg.eq:* $pg.eq*g.eq = (1+tig)*(pgd.eq*(g.eq-gm.eq)+ pgm.eq*gm.eq),$

(118)   *pgm:* $pgm = pgm.eq + pgmv1*pgrow.eq*(z-z.eq)$
$+ pgmv2*(pgrow-pgrow.eq)*z.eq - pgmadj,$

(119)   *pgm.eq:* $pgm.eq = (1-pgm1)*pgm.eq(-1)+ pgm1*pgrow.eq*z.eq,$

(120)   *pgd:* $pgd = pgd.eq + pgdv1*(y/y.eq-1) - pgdadj,$

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21.   These price relatives are accounted for at factor cost. We chose to keep the mnemonics as simple as possible, given that the accounting convention is very clear in the way indirect taxes enter all the identities.

(121)   *pxm:* $pxm = pm,$

(122) p*xm.eq:* $pxm.eq = pm.eq,$

(123)   *px:* $px = px.eq + pxv1*pxrow.eq*(z-z.eq) + pxv2*(x/x.eq-1) +$
                                       $pxv3*(pxrow-pxrow.eq)*z.eq - pxadj,$

(124)   *px.eq:* $px.eq = (1-px1)*px.eq(-1) + px1*pxrow.eq*z.eq,$

(125)   *pm:* $pm*m = pcm*cm + pkm*im + pgm*gm + pxm*xm,$

(126)   *pm.eq:* $pm.eq*m.eq = pcm.eq*cm.eq + pkm.eq*im.eq + pgm.eq*gm.eq$
                                       $+ pxm.eq*xm.eq,$

(127) *check2:* $pfc.eq*y.eq = 1*(pcd.eq*(c.eq-cm.eq) + pkd.eq*(i.eq-im.eq)$
                                       $+ pgd.eq*(g.eq-gm.eq)) + px.eq*x.eq- pxm.eq*xm.eq$
                                       $+ check2,$

(128) *pcd.eq:pcd.eq*(c.eq-cm.eq) + pkd.eq*(i.eq-im.eq) + pgd.eq*(g.eq-gm.eq)*
                                       $= c.eq-cm.eq + i.eq-im.eq + g.eq-gm.eq,$

(129)   *pcd:pcd*(c-cm) + pkd*(i-im) + pgd*(g-gm)*
                                       $= c-cm + i-im + g-gm,$

(130) *pgd.eq:* $pgd.eq = pgd.eq(-1)*(1+0.2*(z.ss/z.ss(-1)-1)),$

(131) *pkd.eq:* $pkd.eq = pkd.eq(-1)*(1+0.2*(z.ss/z.ss(-1)-1)),$

(132)   *z.ss:* $z.ss = z.ss(1).$

Consider, for example, the first block of four equations. Equation (110) provides for adjustment of the equilibrium price of consumption imports, *pcm.eq,* to the world level of the consumption good price. We make this relatively rapid. Equation (109) provides the dynamics of the actual consumption import price, *pcm.* Here, as in all similar equations, we add two types of dynamic disequilibrium effect. The first one is intended to capture the effects of changes in the exchange rate when the *.eq* prices are not disturbed. Thus, in shocks where there is a temporary depreciation of the currency, this term will provide for some temporary effects on consumption import prices. The second term is there to permit us to add extra dynamics for world shocks, where

world relative prices may be expected to deviate temporarily from their *.eq* values.[22] Equations (108) and (107) define the *.eq* and actual levels of overall consumption prices as weighted averages of the domestic price and the import price. As in QPM, we assume that there are no tariffs; the market price reflects the indirect tax on consumption goods, at rate *tic*. Finally, the domestic relative consumption price is linked to PDFC through equations (127) and (128). The equations for investment and government absorption prices are similar in structure.

Export prices are also linked to a world price. We note, in passing, that we make a simplifying assumption for the pricing of the direct import component of exports. We assume that these goods are priced as the average import good. This does two things. It simplifies the import price accounting and eliminates any effect of this component on overall import prices. It also eliminates any potential problem with economic rents available from just changing the scale of re-exporting. In this formulation, exporters make no surplus profits from importing for re-export. None of this is essential, but we find this the simplest way to handle this odd, but empirically important, component of Canadian trade.

The two somewhat unusual equations at the end are devices to allow for endogenous movement in the *.eq* values of two of the domestic price relatives in those cases where the steady-state real exchange rate changes in a shock. This particular formulation picks up that effect using the value from the first-period of the simulation (the new SS solution) relative to the lag (the old, control solution), passing some of that into *pkd.eq* and *pgd.eq*. The identity then completes the system and proximately determines what happens to *pcd.eq*. All of this is ad hoc, in the sense that we have no formal market structure to apply to solve for changes in the domestic price relatives. But without something like this, all the effect ends up in the variable chosen for the normalization of the identity (here, the *pcd.eq* equation). So, we spread the effect, as shown.

2.16.1 Foreign relative prices

The following four equations serve only to provide a framework for introducing different forms of foreign shock. In all cases, foreign prices are exogenous. But we want to be able to distinguish permanent shocks from temporary shocks. The *.eq* parts are intended to represent the

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22. These terms were included in CPAM to enable us to consider world economy shocks in the stochastic simulation project for which this model was built. In the end, this feature of the model was not exploited in Black, Macklem, and Rose (1997); these terms are all set to zero.

permanent part of foreign price structure. In the default mode, all the shock terms are zeros, but these terms can be used to construct an exogenous foreign cycle if needed.

(133) *pcrow:*   *pcrow = pcrow.eq + pcrowshk,*

(134) *pkrow:*   *pkrow = pkrow.eq + pkrowshk,*

(135) *pgrow:*   *pgrow = pgrow.eq + pcrowshk,*

(136) *pxrow:*   *pxrow = pxrow.eq + pxrowshk.*

Note that these are all relative prices. Each is deflated by whatever base foreign price is used implicitly or explicitly in transforming between real and nominal exchange rates. Take, for example, the *pcm.eq* equation, written in SS form (with all the adjustment completed): *pcm.ss = pcrow.ss*z.ss.* If uppercase symbols are the original, undeflated values, we have *PCM.ss = PCROW.ss*S,* where *S* is the nominal exchange rate. As usual, we deflate by PDFC. Here, however, we need an extra step to finish the foreign part. Let *PW* be some numeraire foreign price. It could be, but does not have to be, the world equivalent to PDFC. We then have:

(137) *pcm.ss:*   *pcm.ss = (PCROW.ss/PW)*(PW/PDFC)*S = pcrow.ss*z.ss.*

The intermediate steps here are not visible in any CPAM equation. But from any simulation, the implicit transform above can be used to retrieve results for the nominal exchange rate. This type of thing is done in a macro we call "postcom," which is introduced in the next section.

2.17   Calibration equations and output transforms

There are a few equations in the core model used for calibration runs and a few more in the output module, over and above those that simply convert units.

2.17.1 Calibration equations

The calibration equations are included to facilitate the imposition of judgment on certain aspects of the numerical steady state. We show here a set of equations that facilitate tuning in desired values for steady-state relative prices. In the first of these, for example, a utility variable *pc_py.eq* is introduced. In normal simulation, this equation just computes the ratio of *PC.EQ* to *PY.EQ* from the model's endogenous determination of these prices. In calibration, however, we exogenize *pc_py.eq* and set it at the desired steady-state ratio. Working back through the relative

price system, we endogenize *pcrow.eq* to make this hold. (In fact, there is a bit more to it, but that is the essential point.)

(138) *pc_py.eq:*   *pc_py.eq   = pc.eq/py.eq,*

(139) *pi_py.eq:*   *pi_py.eq   = pi.eq/py.eq,*

(140) *pg_py.eq:*   *pg_py.eq   = pg.eq/py.eq,*

(141) *px_py.eq:*   *px_py.eq   = px.eq/py.eq,*

(142) *pm_py.eq:*   *pm_py.eq   = pm.eq/py.eq.*

2.17.2 The postcom macro

It is most convenient to simulate the core model in detrended form. However, it is, of course, essential to be able to reintroduce trend real growth and trend inflation to the output. Also, there are various measures one might want to see that are transforms of core output, such as cumulative gap measures or cumulative price drift measures. All of this is provided in a macro, called postcom, for ex post computations. This is also where we compute all the annual rate measures and level measures.

3. The dynamic properties of CPAM

In this section, we describe aspects of CPAM's properties by presenting the results of eight shocks. We begin with some temporary shocks.

3.1 A temporary demand shock

The first shock is a temporary increase in demand that increases aggregate demand by 1 per cent, from exogenous increases in both consumption and investment. Consumption increases by 2 per cent and investment by 1 per cent.

A first-pass analysis of this shock is straightforward. The increase in demand leads to an increase in inflation, which the monetary authority counteracts by increasing interest rates. This, with the associated appreciation in the real exchange rate, reduces demand and eventually there is excess supply. Inflation turns, and eventually, by the fifth year, returns to control. Notice how the monetary authority is able to do this with little cycling.
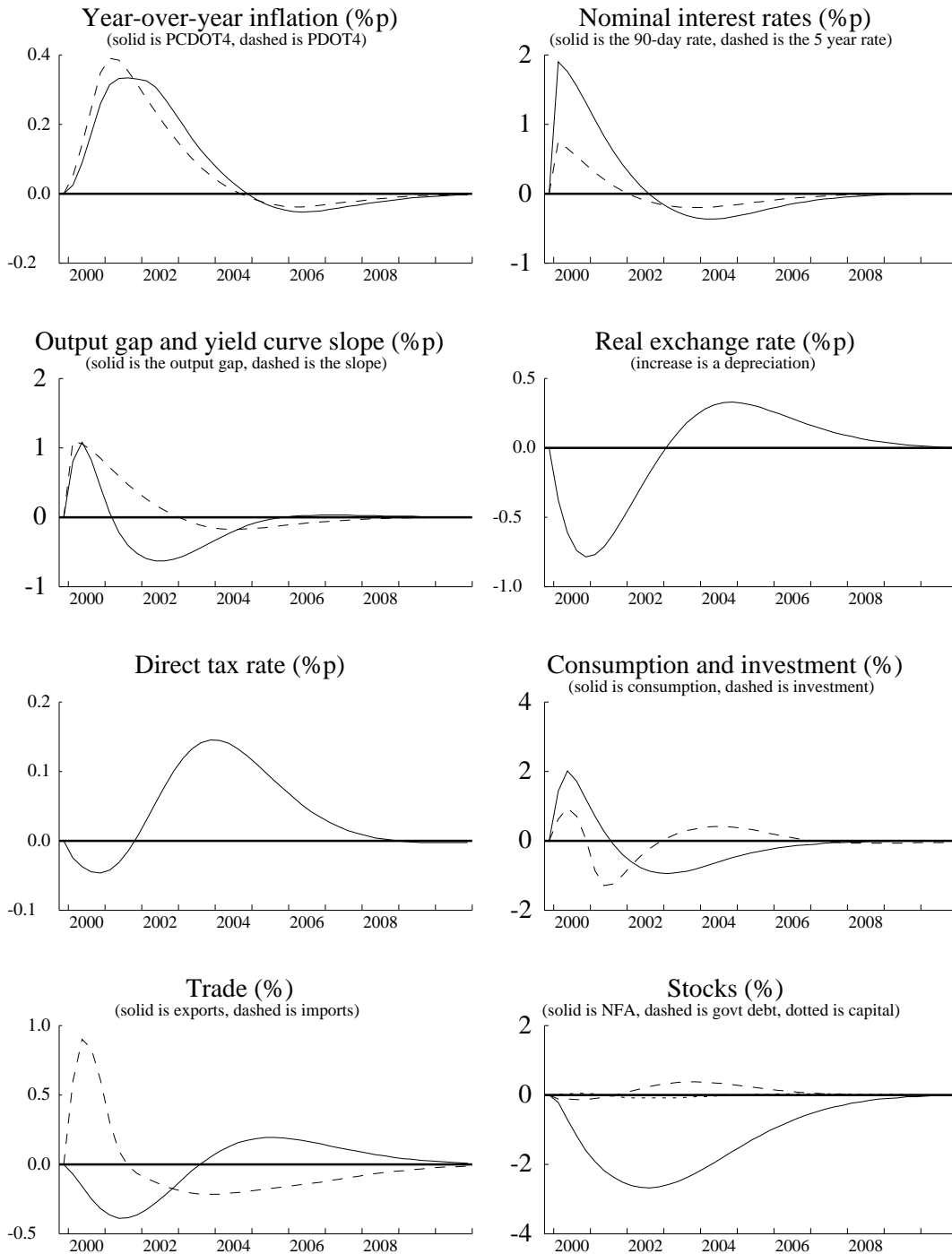
It is possible to garner more from this shock than the simple analysis above. First, it provides an example of how the dynamic solution returns to the steady state when the model is perturbed. Notice how all three stocks, government debt, physical capital, and net foreign assets, return to the control after about 10 years. Government debt falls initially as tax revenues increase with demand. In response, the government reduces the tax rate and the level of government debt begins to return to its target level. Capital increases slightly with the increase in investment.[23] However, this latter increase is reversed quite quickly by the interest rate increases, and capital returns to its equilibrium level. Finally, the economy runs a trade deficit over the general course of the shock, owing to the increase in demand for imported consumption and investment goods and the reduction in exports brought about from the appreciation in the currency.

Although a better example is provided in the next subsection, a second more subtle illustration of one of CPAM's properties is how the shock leads to a greater increase in inflation of PDFC compared with that of *PC*. This reflects the exchange rate pass-through into *PC*, which in this case acts to dampen the inflationary pressure stemming from excess demand.

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23. Note that due to the large increase in output, the ratio of capital to GDP actually falls.

Figure 1: A demand shock
(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

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3.2   A temporary exchange rate shock

This shock, where the real exchange rate depreciates by a little over 1.2 percentage points, highlights how the real exchange rate affects prices and the real economy in CPAM.
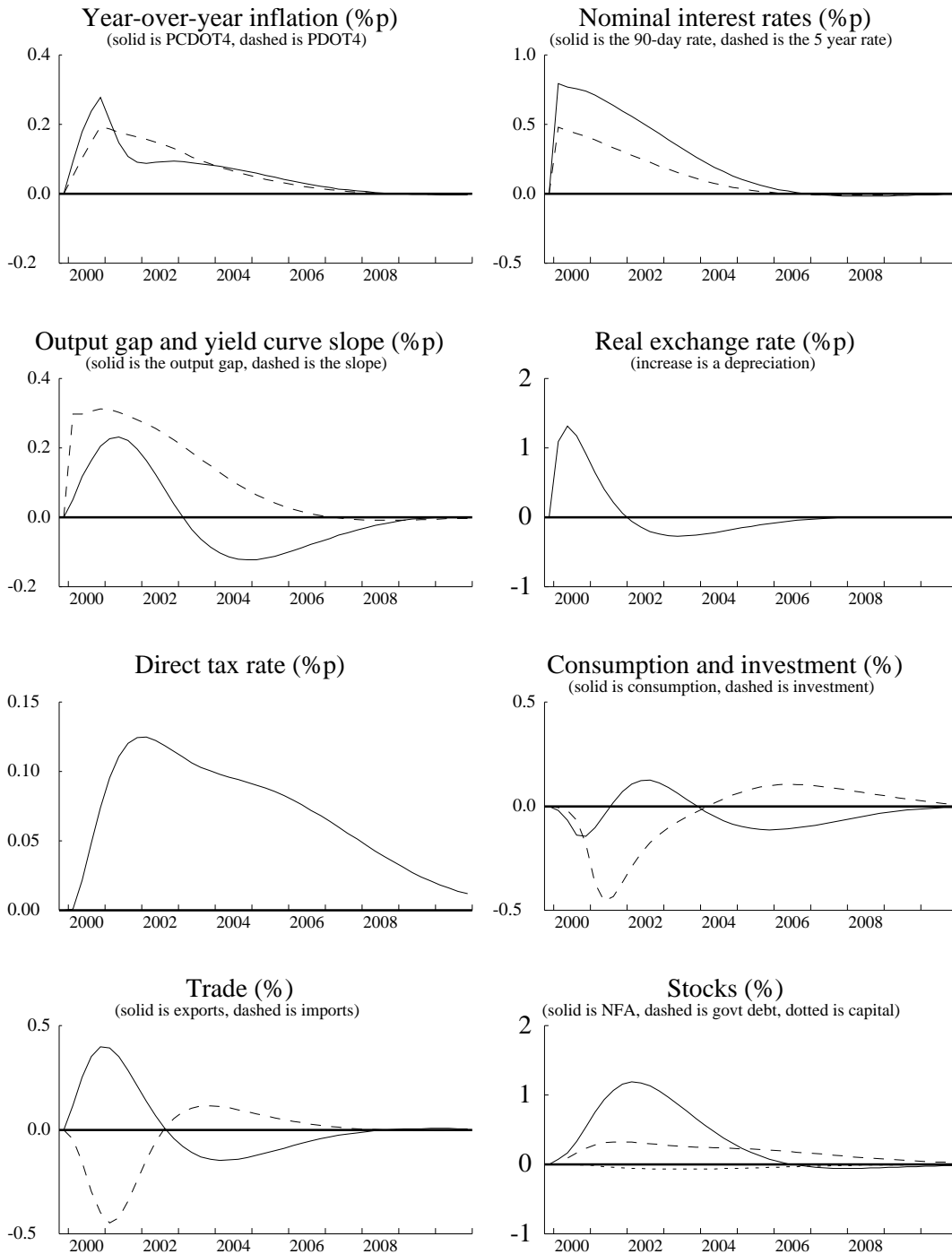
The real exchange rate operates first through prices and from there the real economy. A depreciation in the real exchange rate means that the price of exports falls and the price of imports rises. These relative price movements affect the components of aggregate demand. Exports rise and imports fall, increasing domestic demand. However, as substantial proportions of consumption and investment goods are imported, the overall relative prices of these goods increase and quantities decrease following an exchange rate depreciation. Overall, the effect on aggregate demand is ambiguous. However, CPAM has been calibrated so that the trade effect dominates and aggregate demand increases.

As in the demand shock, the increase in aggregate demand, together with a direct price effect described below, induces some inflation and consequently a tightening by the monetary authority. In passing, it is worth emphasising that this tightening is purely a response of the monetary authority to return inflation to its target rate, rather than a desire to target or smooth the exchange rate in any direct sense. As before, the economy returns to control following a period of stock adjustment.

There is an interesting "blip" in the shock minus control results for the rate of inflation in consumer prices, *PCDOT4*, which corresponds with the initial spike in the exchange rate. Notice how *PCDOT4* jumps over 0.25 percentage points, then quickly falls to 0.1 percentage points above control, before gradually returning to control. In contrast, the PDFC deflator jumps by only 0.2 percentage points initially and then immediately starts its gradual return to the target—there is no jump down or "blip." The reason for this difference is the exchange rate effect. Imported goods have a direct effect on consumer prices, but only an indirect dynamic effect on the PDFC deflator, so the depreciation of the exchange rate feeds more quickly into *PC* inflation. Conversely, when the exchange rate starts to appreciate in response to the rise in interest rates, the rate of PC inflation falls more sharply, leading to the "blip."

Figure 2: An exchange rate shock
(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

3.3 A temporary tightening in monetary conditions

This shock is intended to illustrate how monetary policy is transmitted through the model. We describe the results of a temporary (four-quarter) increase in the intermediate monetary target—the slope of the term structure of interest rates.
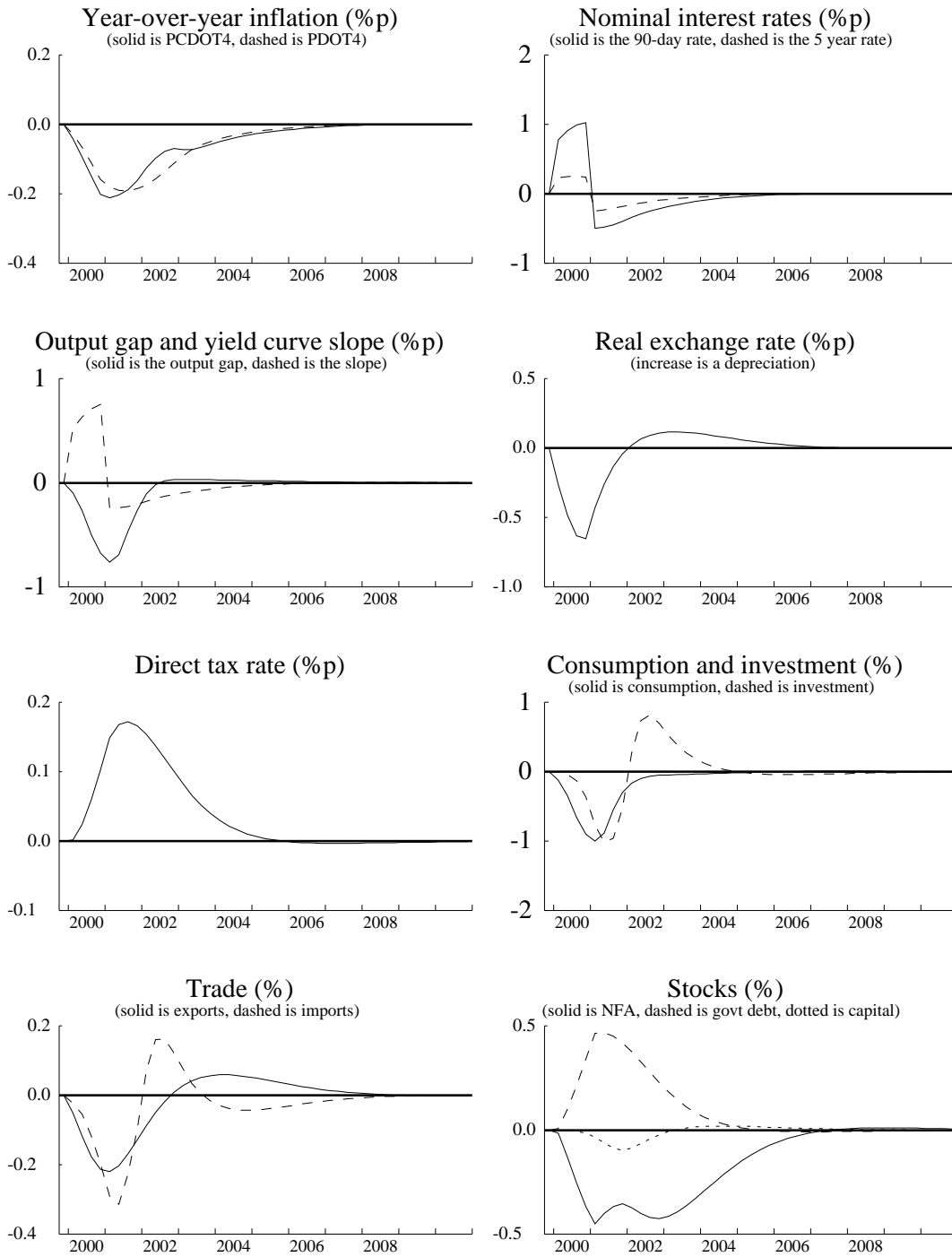
The net effective shock is shown in the second panel, left side, of Figure 3. For this shock, we have left the normal monetary reaction function to operate. Since the economy weakens and inflation falls in response to the shock, the endogenous response is to reverse part of the shock.

As has already been discussed, monetary policy acts first through the exchange rate, and then through aggregate demand. As shown in the figure, the exchange rate appreciates by a little over 0.5 percentage points, before starting to depreciate back towards the control solution. The weakening of aggregate demand lags this reaction by a couple of quarters. The exchange rate response itself contributes to the transmission of the shock to the real economy, as exports decline relatively quickly. As the interest rate effects on domestic demand begin to bite, however, the trade effects become dominated by the profile of imports, which reflect the cycle in investment spending.

The results of an exchange rate appreciating faster than demand is falling can also be inferred by comparing the fall of *PC* inflation compared with PDFC inflation. The former falls faster, again about two quarters sooner, than the latter.

As is to be expected, the tightening of monetary conditions for no particular reason necessitates an offsetting loosening over the medium term to return inflation to the target level. Inflation returns to the target after about six years.

Figure 3: A temporary tightening in monetary conditions

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)
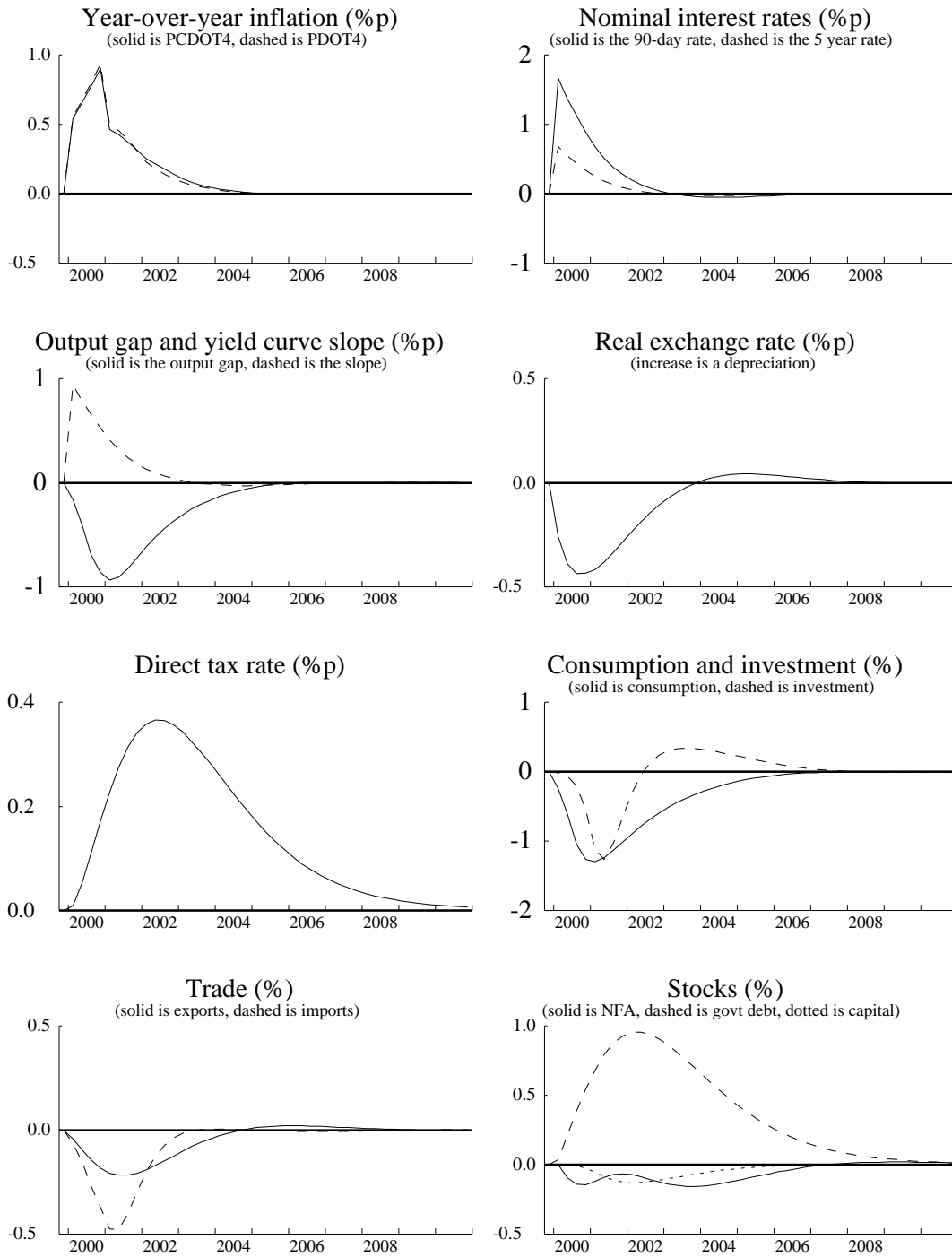
3.4   A temporary increase in inflation

This shock reports the results of a temporary increase in inflation. More specifically, the residual associated with the Phillips curve is shocked for one quarter. The shock, however, is substantial enough to raise the four-quarter inflation rate by close to a percentage point by the end of the first year.

The mechanics of the shock are straightforward. The monetary authority tightens in order to bring inflation back to the target rate. This tightening triggers an exchange rate appreciation, which helps reduce inflation via a direct effect on consumer prices of lower import prices as well as by reinforcing the effect of higher interest rates in reducing aggregate demand by discouraging exports. The substitution of cheaper imports for domestic goods in consumption also works to reduce domestic demand. Aggregate demand falls by about 1 per cent in the first year, and inflation is back at control within three years.

The profile of the monetary response is worth noting. As in the demand shock, the forward-looking monetary authority raises rates sharply and then begins to reduce them long before inflation is back to the target rate. As a result, there is not a lot of overshooting and secondary cycling.

One small point of interest in this shock is that there is some degree of policy co-ordination in the response. The monetary tightening leads to lower tax revenues, and the government finances its activity with a temporary increase in the deficit causing debt to rise above the target level. The response is to raise the tax rate, which helps reduce spending, assisting the monetary authority in resisting the temporary surge in inflation.

Figure 4: A temporary increase in inflation

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

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3.5 An increase in world commodity prices

In this shock, the price of world commodities rises. In CPAM, this shock is introduced as a 10 percentage point increase in the relative price of Canadian exports in world markets.
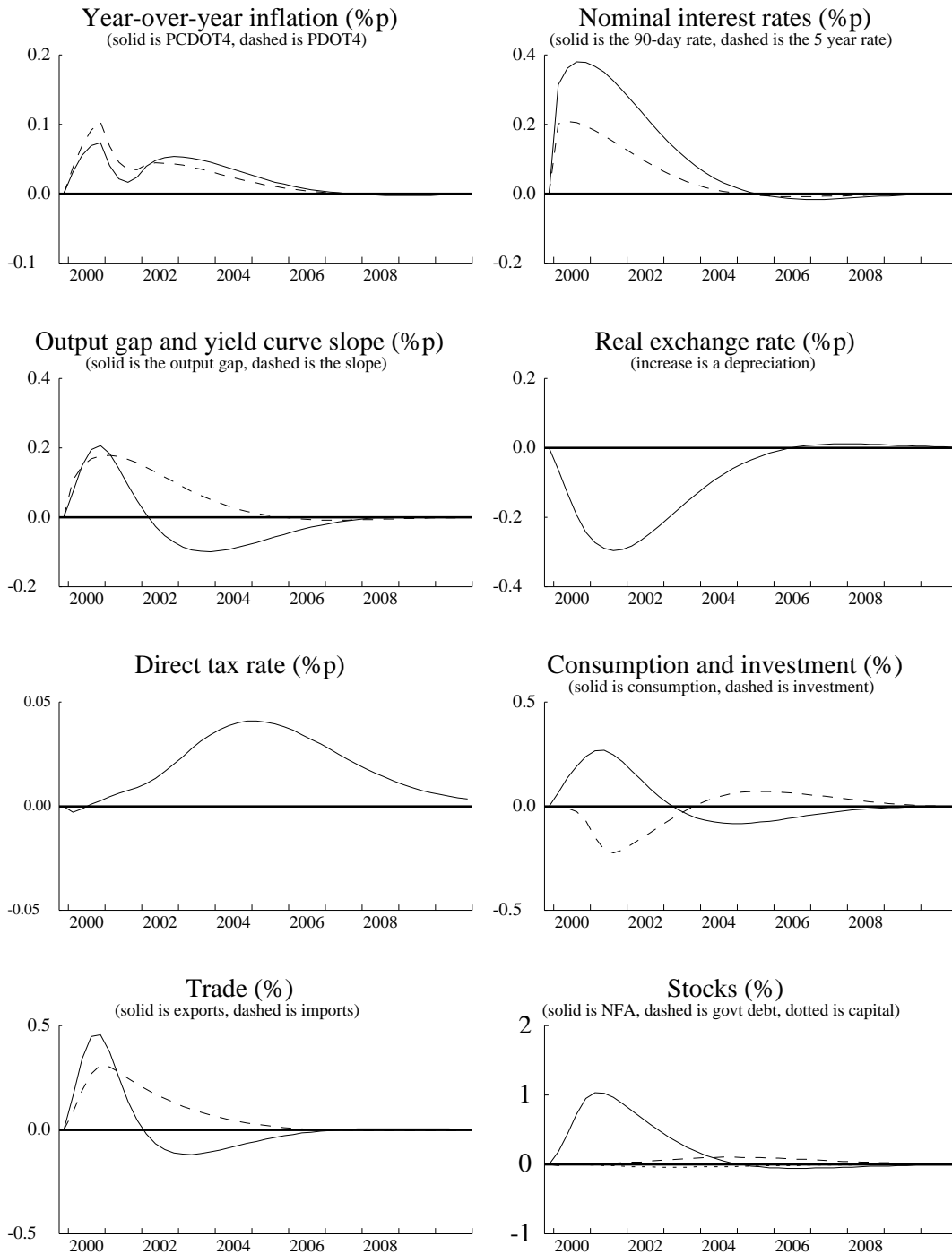
As CPAM is a model of a small open economy, exporters are price takers. This means that when prices increase, exporters increase their production, and aggregate exports increase. In addition, as the shock represents an increase in wealth for consumers, this increase is echoed in the consumption sector. Overall, aggregate demand increases, and this kicks off an inflation and monetary policy response that is familiar from the demand shock in Section 3.1. There is also an apparent difference between the *PC* and PDFC inflation measures stemming from the exchange rate appreciation, just as in Section 3.2.

Note the initial decline in aggregate investment. It might be reasonable to expect an increase here to reflect exporters building up their capital stock. That investment actually falls is due to the relative price effect, from the appreciation in the dollar, and the impact of the rise in interest rates, which outweigh the (small) direct effect. This is consistent with the results reported by Macklem (1993) from a more complete (multi-sector) model. An important point here is that firms know that this particular shock is temporary. Although we do not show this here, we can report that if the shock were permanent, there would be a strong increase in investment due to the larger direct effect.

The changes in the real exchange rate here have both a real and a policy (interest rate) component. The effect of the interest rate is as described above, and operates through the uncovered interest parity condition (equation 100). The real component comes from the role of the real exchange rate in supporting the overall asset equilibrium (see Section 2.11). For a given level of net foreign debt, higher export prices mean that less real output is needed to service that debt. The pressure is thus for the exchange rate to appreciate to remove some of the shock. One can also think of this as part of the mechanism whereby the favourable terms-of-trade shock gets passed on to households. The real appreciation makes imports cheaper and facilitates the brief surge in consumption.

Figure 5: An increase in commodity prices

(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

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3.6   An increase in total factor productivity

So much for temporary shocks; we now turn to permanent shocks. In this shock, the level of total factor productivity increases permanently by 1 per cent.

Such a change has a permanent effect on the steady state of CPAM—all real levels increase by just over 1.5 per cent (the equivalent increase in labour productivity). However, no ratio of prices or real variable changes.[24] The only exception is relative factor prices; the real wage, however measured, rises to reflect the higher productivity.

The adjustment to the new steady state commences with an investment boom, as firms put new capital in place to take advantage of the higher level of productivity. Households also increase their consumption, in response to their new-found wealth. Both these effects contribute to a large increase in imports. Exports, too, increase to their new equilibrium level. Overall, the increase in imports outstrips that of exports, as it must in order that *NFA* fall to its new equilibrium level.[25]
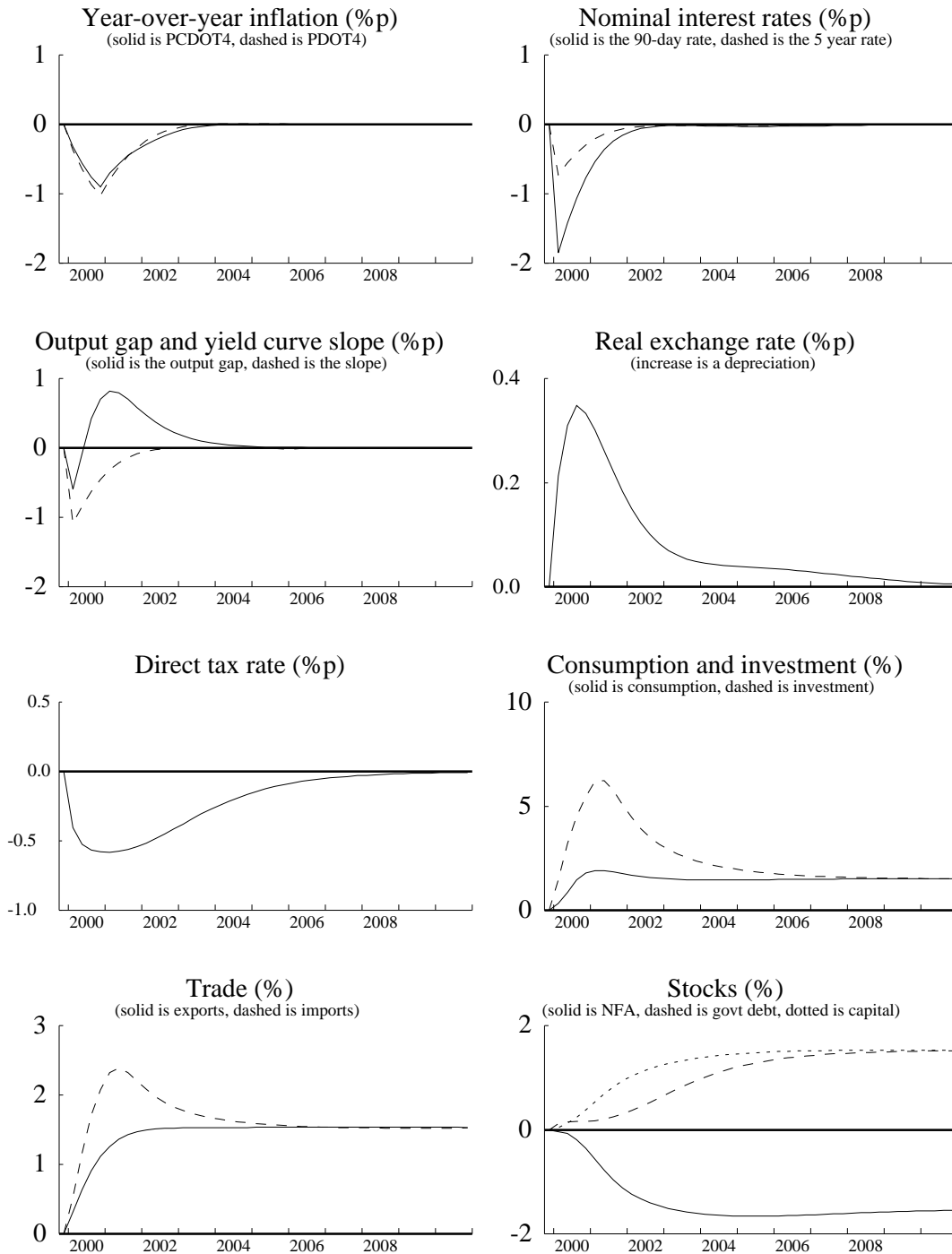
As, initially, supply outstrips demand, the shock is deflationary. In addition, as nominal wages are sticky, firms pay workers less than their marginal product in the short run. Competition among firms then leads to a reduction in the inflation rate as firms reduce their (increases in) prices in line with their lower marginal cost.

Overall, *PC* inflation falls by a little under 1 percentage point, and the monetary authority loosens monetary conditions accordingly.

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24. This is different from QPM where the economy is not, strictly speaking, a small open economy so the increase in domestic productivity leads to a modest depreciation in the exchange rate. This, in turn, affects the cost of capital and the rest of the model.

25. As Canada is a net debtor, *NF*A is negative. In order that the *NFA*-to-GDP ratio be constant, this means that *NFA* must decrease (i.e., become more negative).

Figure 6: An increase in total factor productivity
(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

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3.7   A change in the target rate of inflation

The last two shocks illustrate how CPAM is useful for analyzing changes in policy. In this subsection, the monetary authority reduces its target inflation rate by 1 percentage point.
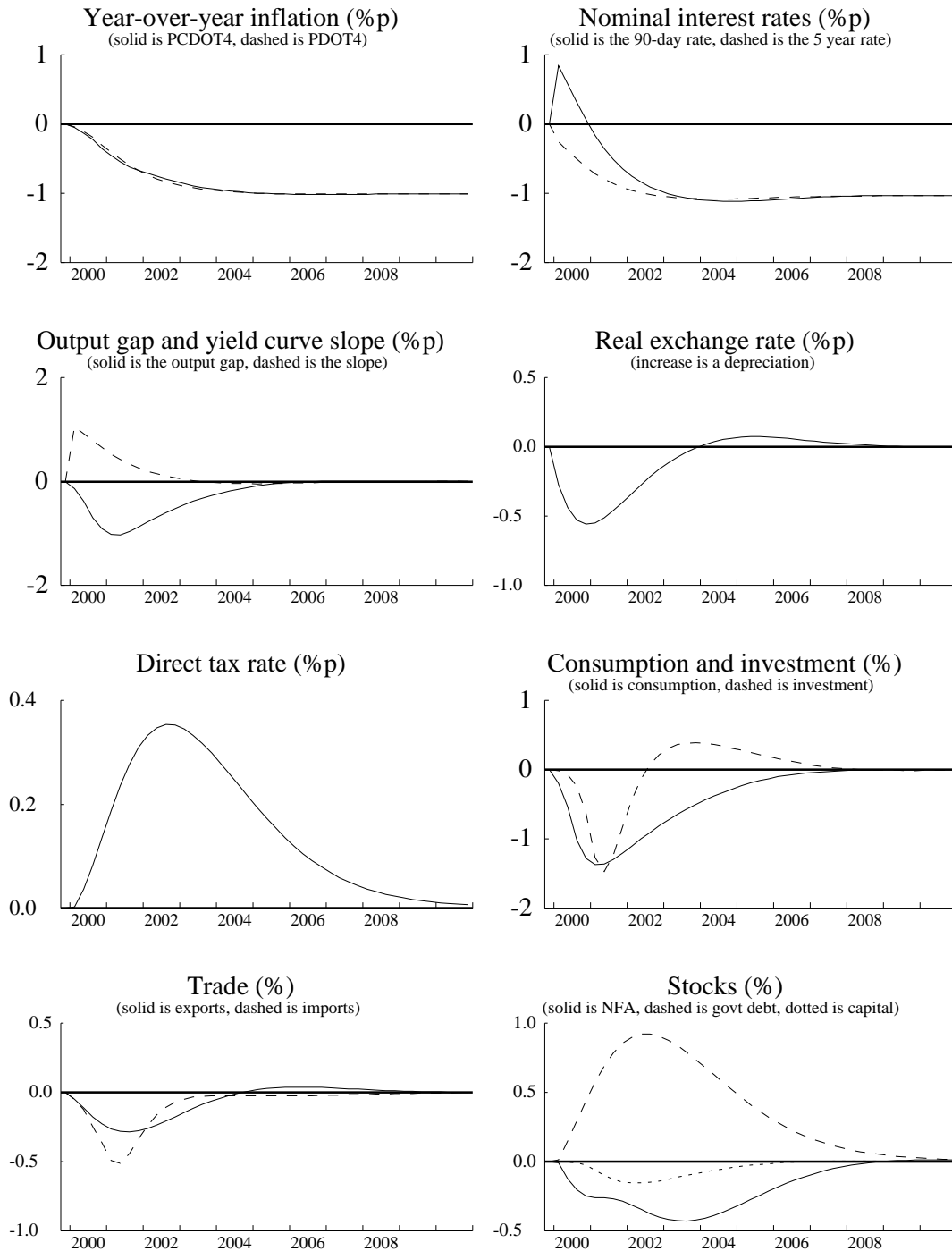
In CPAM, there are no free lunches in the form of announcement effects, so the monetary authority must tighten monetary conditions in order to reduce the inflation rate to its new level. It does so, and the slope of the yield curve increases by 1 percentage point in the first year. This triggers an appreciation of the currency, which helps move consumption prices down, initially, and also adds to the reduction of aggregate demand through the trade balance. A negative output gap emerges, and the inflation rate declines until it reaches its new target level.

This shock also illustrates some aspects of interest rate determination in CPAM. In CPAM, the long-term rate is based on the expectations hypothesis, but with a little extra weight on current conditions, such that the long rate tends to move more with the short rate than would be predicted by the expectations hypothesis. Nevertheless, as the monetary authority has credibility, in the sense that agents know that it will carry out the planned reduction in the rate of inflation, the long-term interest rate falls immediately.[26] This means that the short rate does not have to be raised as much as the slope to achieve the objective. In this respect, it is interesting to contrast this shock with the temporary shock to inflation in Section 3.4. There, in contrast, the long rate rises with the short rate, and so the short rate has to rise relatively more to reverse inflation than it does here to reduce it.

One common measure of the costs of disinflation, is the sacrifice ratio, measured as the cumulative loss in output necessary to reduce inflation permanently by 1 percentage point. CPAM has been calibrated to have a sacrifice ratio of just under 2.7, which is slightly less than in QPM.

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26.   In QPM, the long rate increases slightly for the first few quarters of the shock.

Figure 7: An decrease in the target rate of inflation

(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

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3.8   A permanent change in government debt

In this shock, the government lowers the target ratio of debt to GDP by 10 percentage points. To analyse this shock, it is convenient to start with the steady-state implications, and then move to the dynamic effects.

The basic result from the steady-state model is that, as the direct tax rate is lower in the end, consumers have more wealth, and this leads to an increase in consumption of 0.46 per cent. The lower tax rate reflects the lower debt-service burden in the new steady state. There is also a substantial reallocation of assets within the portfolio, as consumers switch from holding government assets to holding net foreign assets. The ratio of net foreign assets to GDP increases by just over 10 percentage points. Finally, a small relative price effect reduces the cost of capital and output increases by 0.03 per cent.[27]

Moving now to the dynamics, we see that a key difference arises from the profile of the personal tax rate. Though it will eventually fall below control, it has to rise sharply at first to secure the revenues to pay off part of the debt. Hence, although consumption is higher in the steady state, the increased tax burden during the adjustment means that consumption over the medium term is depressed. Indeed, consumption falls by over 6 per cent, relative to control, in the first couple of years of the shock, and does not rise above control until year five. Such a large reduction in consumption leads to a significant decline in imports, and it is this, supported by a depreciation in the currency and the consequential increase in exports, that facilitates the substitution away from government debt towards net foreign assets.

The short-term implications of the shock for the monetary authority are interesting. Overall, the economy is in a position of excess supply, so PDFC inflation falls. However, the strong depreciation of the currency causes the inflation rate, as measured by consumer prices, to increase slightly in the first year before the effects of depressed demand pull it down too. As the monetary authority looks past the initial rise in consumer price inflation to the period where it will be below control, they loosen monetary conditions from the start. With a less forward-looking policy rule, there would be less willingness to ease early and to let the exchange rate depreciate as part of the adjustment.

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27.   The reader is referred to Black, Laxton, Rose, and Tetlow (1994) for a more detailed discussion of the steady-state implications of this shock.

Figure 8: An decrease in the target debt-to-GDP ratio

(% is per cent shock minus control, %p is percentage points shock minus control)

Year-over-year inflation (%p)
(solid is PCDOT4, dashed is PDOT4)

Nominal interest rates (%p)
(solid is the 90-day rate, dashed is the 5 year rate)

Output gap and yield curve slope (%p)
(solid is the output gap, dashed is the slope)

Real exchange rate (%p)
(increase is a depreciation)

Direct tax rate (%p)

Consumption and investment (%)
(solid is consumption, dashed is investment)

Trade (%)
(solid is exports, dashed is imports)

Stocks (%)
(solid is NFA, dashed is govt debt, dotted is capital)

APPENDIX A: The adjustment mechanism in CPAM

This appendix describes the generic adjustment process used in CPAM. CPAM has dynamics arising from three main sources. The first is intrinsic dynamics, that is, dynamic structure that arises from the tendency for economic agents to adjust gradually to disturbances, even when those disturbances are understood perfectly. Such behaviour arises when adjustment is costly. The other two general sources of dynamic structure in CPAM are expectations formation and the endogenous response of monetary and fiscal policy to economic conditions. The focus of this appendix is on the first source; the other two have been addressed in the main text.

In CPAM, intrinsic dynamics are modelled as the solution to a quadratic optimization problem. In this problem, agents must weigh a cost of being away from a target with the cost of adjusting towards it. The result is that agents adjust "slowly" towards the new target, with "slowly" being defined as a matter of calibration. The following discussion is based on Pesaran (1991) and particularly on the formulation in Tinsley (1993).

The generic dynamic adjustment model

Let y be the variable to be modelled, and y^* its "desired" value in the absence of adjustment costs. At time t, the general intrinsic adjustment model is derived from choosing $y_{t+\tau}$, for $\tau \geq 0$, to minimize the following cost function:

$$(A1) \; E\left[\sum_{\tau=0}^{\infty} (y_{t+\tau} - y_{t+\tau}^*)^2 + 0.5 \sum_{i=0}^{n} \phi_i (A_i(L) y_{t+\tau})^2 \right],$$

where $A_i(L)$ is a polynomial in the lag operator and n is the order of the adjustment process. The first term of this equation penalizes being away the desired level. The second term, which is made up of n quadratic terms of past values of y, is chosen so as to penalize changes in y. Note that, given the definitions of A_i below, having high ϕ weights will penalize changes in y and lead to gradual adjustment.

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In CPAM, two different forms for A_i are used, depending on whether the adjustment is for a stock or not. If the adjustment is for a flow or a relative price, then A_i is chosen so that changes in the ith (equally-weighted) moving average of y are penalized. This change is given by

$$(A2) \sum_{j=0}^{i} (y_{t+\tau-j}) - \sum_{j=0}^{i} (y_{t+\tau-1-j}) = y_{t+\tau} - y_{t+\tau-1},$$

so that A_i is given by

$$(A3) A_i(L) = 1 + L^{i+1}.$$

For stocks, in particular capital, A_i is chosen so that changes in the ith difference of y are penalized. This leads to the definition

$$(A4) A_i(L) = (1-L)^i.$$

Having these two different styles of adjustment costs facilitates the calibration of the model. For flows, the data suggest that past flows are good indicators of the current flow. This is captured in the model by placing high ϕ weights on changes in moving averages. As can be seen in equation (2), this penalizes a movement in y compared to what it was in the past. For stocks, the problem is slightly different. In this case, it was found that, when the first form of adjustment is used, even though the dynamics of stock itself look fine, the flows resulting from the changes in the stock are very volatile. The second form, which penalizes differences, provides a similar path for the level of the stock, but one with smoother changes in flows.

The solution to minimization of (1) is a straightforward application of dynamic programming, and results in an Euler equation in n lags and n leads.[28] In CPAM, the equations are left in this form, unlike in QPM where they are rewritten as an infinite sum and truncated. The leads are taken to be model-consistent expectations. The solution can be written in the form:

$$(A5) y = y^* - yadj,$$

as in the main text, where $yadj$ is a function that depends on $n-1$ leads and lags of y as well as the parameters in A and ϕ.

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28. In CPAM, these Euler equations are generated using a TROLL macro.

An example of a customized equation

Take the case of the model's equation for the dynamics of consumer spending (by forward-looking consumers). This is given by a fourth-order adjustment model that penalizes changes in moving averages. The target rate is given by

$$(A6)\quad cfl^* = cfl^{eq} - \lambda_1(r - r^{eq}) + \lambda_2(nfa - nfa_{eq}) + cflshk.$$

In addition to the equilibrium value of consumption, there are several other terms in this equation. The first two, with coefficients λ_1 and λ_2, are there to capture special features of cyclical correlation among economic variables. These have been described in the main text. There is also a third extra term, $cflshk$, that can be used to shock consumption.

The solution to this, as noted in (5), can be written as

$$(A7)\quad cfl = cfl^{eq} - \lambda_1(r - r^{eq}) + \lambda_2(nfa - nfa_{eq}) + cflshk - cfladj.$$

For completeness, the $cfladj$ term is included below. For this equation, we return to TROLL syntax; it is the equation exactly as generated by the TROLL macro described earlier.

(A8) *CFLADJ* *CFLADJ* = *CD1**(1*1*1*(1*1*CFL(0)-1*1*CFL(-1))

-1*1*CB1**1*(1*1*CFL(1)-1*1*CFL(0)))+CD2*(1*1*1*(1*1*CFL(0)

-1*2*CFL(-1)+1*1*CFL(-2))-1*2*CB1**1*(1*1*CFL(1)

-1*2*CFL(0)+1*1*CFL(-1))+1*1*CB1**2*(1*1*CFL(2)

-1*2*CFL(1)+1*1*CFL(0)))+CD3*(1*1*1*(1*1*CFL(0)

-1*3*CFL(-1)+1*3*CFL(-2)-1*1*CFL(-3))-1*3*CB1**1*(1*1*CFL(1)

-1*3*CFL(0)+1*3*CFL(-1)-1*1*CFL(-2))+1*3*CB1**2*(1*1*CFL(2)

-1*3*CFL(1)+1*3*CFL(0)-1*1*CFL(-1))-1*1*CB1**3*(1*1*CFL(3)

-1*3*CFL(2)+1*3*CFL(1)-1*1*CFL(0)))+CD4*(1*1*1*(1*1*CFL(0)-

1*4*CFL(-1)+1*6*CFL(-2)-1*4*CFL(-3)+1*1*CFL(-4))

-1*4*CB1**1*(1*1*CFL(1)-1*4*CFL(0)+1*6*CFL(-1)

-1*4*CFL(-2)+1*1*CFL(-3))+1*6*CB1**2*(1*1*CFL(2)

-1*4*CFL(1)+1*6*CFL(0)-1*4*CFL(-1)+1*1*CFL(-2))

-1*4*CB1**3*(1*1*CFL(3)-1*4*CFL(2)+1*6*CFL(1)-1*4*CFL(0)

+1*1*CFL(-1))+1*1*CB1**4*(1*1*CFL(4)-1*4*CFL(3)+1*6*CFL(2)

-1*4*CFL(1)+1*1*CFL(0)))

APPENDIX B:Mnemonics, descriptions, and values

This appendix contains the mnemonics and descriptions of the variables and parameters in the model CPAM. They are grouped by endogenous, exogenous, and parameter types. Variables that are exogenous for calibration only are labelled as such with an indication to the corresponding variable that is made endogenous. The values shown for exogenous and endogenous variables are their steady-state values.

Table 1: Exogenous variables

Mnemonic	Description	Value
CM_C0	Level term in the *cm* share equation (calibrated from *cm_c.eq*)	1.14638
CSHK	Shock term in the consumption model equation	0.00000
DELTA	Discount factor of consumers (calibrated from *nfa*)	0.99062
DSHK	Shock term for demand shocks	0.00000
GBTAR_Y.EQ	Equilibrium target ratio of government bonds to output	1.93800
GM_G0	Level term in the *gm* share equation (calibrated from *gm_g.eq*)	1.36238
GTR_Y.EQ	Equilibrium target ratio of government transfers to output	0.14000
G_Y.EQ	Equilibrium target ratio of government expenditure to output	0.18500
IM_I0	Level term in the im share equation (calibrated from *im_i.eq*)	1.59147
KSHK	Shock term in the capital model equation	0.00000
NDOT.EQ	Equilibrium population growth rate	0.00235
PCROW.EQ	Equilibrium world price of imported consumption goods (calibrated from *pc_py.eq*)	0.99381
PCROWSHK	Shock term in the *pcrow* equation	0.00000
PDOTSHK	Shock term in the inflation equation	0.00000
PDOTTAR.EQ	Equilibrium target inflation rate	0.00249
PGROW.EQ	Equilibrium world price of imported government goods	1.09655
PKROW.EQ	Equilibrium world price of imported investment goods	0.76053
PKROWSHK	Shock term in the *pirow* equation	0.00000
PSHIFT	Shock term in the unemployment model equation	0.00000
PXROW.EQ	Equilibrium world price of export goods	1.02533
PXROWSHK	Shock term in the *pxrow* equation	0.00000
QDOT.EQ	Equilibrium growth rate of labour augmenting technical progress	0.00325
RCON_R.EQ	Equilibrium real risk premium for consumers	0.00992
RGB_R.EQ	Equilibrium real risk premium on government bonds	0.00367
RK_R.EQ	Equilibrium real risk premium on capital	0.04524
RNFA_R.EQ	Equilibrium real risk premium on *NFA*	0.00469
RROW.EQ	Equilibrium real interest rate in the rest of the world	0.00705
RSLSHK	Shock term in the *RSL* equations	0.00000
RT5.EQ	Equilibrium 5-year term premium	0.00125
TFPSHK	Shock term in the *tfp* equation	0.00000
TIC.EQ	Equilibrium indirect tax rate on consumption goods	0.16540
TICM.EQ	Equilibrium tariff rate on imported consumption goods	0.00000
TIG.EQ	Equilibrium indirect tax rate on goverment goods	0.03000
TIGM.EQ	Equilibrium tariff rate on imported government goods	0.00000
TII.EQ	Equilibrium indirect tax rate on investment goods	0.08000
TIIM.EQ	Equilibrium tariff rate on imported investment goods	0.00000
TK.EQ	Equilibrium tax rate on profits	0.07500

Table 1: Exogenous variables

Mnemonic	Description	Value
TUNE_RSL	Utility variable for delaying monetary policy response	1.00000
TUNE_Z	Utility variable for holding the exchange rate fixed, temporarily	1.00000
U.EQ	Equilibrium rate of unemployment	0.08000
USHK	Shock term in the unemployment model equation	0.00000
WSHK	Shock term in the real wage equation	0.00000
XM_X.EQ	Equilibrium ratio of imports for re-export (calibrated from *x.eq*)	0.34921
X_Y0	Level term in the equilibrium export equation (calibrated from *z*)	-0.59507
ZSHK	Shock term in the real exchange rate equation	0.00000

Table 2: Endogenous variables

Mnemonic	Description	Value
C	Consumption	0.17300
C.EQ	Equilibrium consumption	0.17300
CC.EQ	Equilibrium user cost of capital	0.06367
CFL	Consumption by forward-looking consumers	0.12209
CFL.EQ	Equilibrium consumption by forward-looking consumers	0.12209
CFLADJ	*cfl* adjustment cost	0.00000
CHECK1.EQ	A check on the equilibrium SNA identity	0.00000
CHECK2.EQ	A check on the equilibrium *PD* identity	0.00000
CM	Imports of consumption goods	0.03308
CM.EQ	Equilibrium imports of consumption goods	0.03308
CM_C	Share of imported consumption goods	0.19120
CM_C.EQ	Equilibrium share of imported consumption goods (calibrates *cm_c0*)	0.19120
CM_CADJ	*cm_c* adjustment cost	0.00000
CRT	Consumption by rule-of-thumb consumers	0.05091
CRT.EQ	Equilibrium consumption by rule-of-thumb consumers	0.05091
D	Demand index *(c+i)*	0.20984
FA	Real financial assets	1.27983
FA.EQ	Equilibrium financial assets	1.27983
FA.SS	Steady-state financial assets	1.27983
G	Real government expenditures	0.04625
G.EQ	Equilibrium government expenditures	0.04625
GB	Real government assets	0.48450
GB.EQ	Equilibrium government assets	0.48450
GBTAR	Government target debt level	0.48450
GM	Imports of government goods	0.01641
GM.EQ	Equilibrium imports of government goods	0.01641
GM_G	Share of imported government goods	0.35490
GM_G.EQ	Equilibrium share of imported government goods (calibrates *gm_g0*)	0.35490
GM_GADJ	*gm_g* adjustment cost	0.00000
GTR	Real government transfers	0.03500
GTR.EQ	Equilibrium government transfers	0.03500
HWFL.EQ	Equilibrium human wealth	5.19519
I	Real investment	0.03684
I.EQ	Equilibrium investment	0.03684
I.SS	Steady-state investment	0.03684
IM	Imports of investment goods	0.02225
IM.EQ	Equilibrium imports of investment goods	0.02225
IM_I	Share of imported investment goods	0.60390

Table 2: Endogenous variables

Mnemonic	Description	Value
IM_I.EQ	Equilibrium share of imported investment goods (calibrates *im_i0*)	0.60390
IM_IADJ	*im_i* adjustment cost	-0.00000
K	Production capital	1.37645
K.EQ	Equilibrium production capital	1.37645
KADJ	*k* adjustment cost	0.00000
M	Imports	0.10697
M.EQ	Equilibrium imports	0.10697
MPCW.EQ	Equilibrium marginal propensity to consume out of wealth	0.02202
NDOT	Population growth rate	0.00235
NETX	Real net exports	0.00229
NETX.EQ	Equilibrium net exports	0.00229
NFA	Net foreign asset ratio	-0.31122
NFA.EQ	Equilibrium net foreign asset ratio (calibrates *delta*)	-0.31122
PC	Relative price of consumption goods	1.17076
PC.EQ	Equilibrium relative price of consumption goods	1.17076
PCD	Relative price of domestic consumption goods	1.01328
PCD.EQ	Equilibrium relative price of domestic consumption goods	1.01328
PCDADJ	*pcd* adjustment cost	0.00000
PCDOT	Inflation rate for *PC*	0.00249
PCDOT4	4-quarter inflation rate for *PC*	0.00249
PCDOTE	Expected *PC* inflation rate	0.00249
PCDOTEA	Effective average expected *PC* inflation rate	0.00249
PCLEVEL	Level price of consumption goods	1.69447
PCLEVELTAR	Optional term for price-level targeting	1.69447
PCM	Relative price of imported consumption goods	0.96787
PCM.EQ	Equilibrium relative price of imported consumption goods	0.96787
PCMADJ	*pcm* adjustment cost	0.00000
PCROW	World price of imported consumption goods	0.99381
PC_PY.EQ	Equilibrium price of consumption relative to *py*	1.02670
PDOT	Inflation rate for PDFC	0.00249
PDOT.EQ	Equilibrium inflation rate	0.00249
PDOT4	4-quarter inflation rate for *P*	0.00249
PDOTE	Expected inflation rate	0.00249
PDOTEA	Effective average expected *P* inflation rate	0.00249
PDOTTAR	Target inflation rate	0.00249
PDOTTARE	Expected target inflation rate	0.00249
PFC	Relative price of output at factor cost	1.01065
PFC.EQ	Equilibrium relative price of output at factor cost	1.01065

Table 2: Endogenous variables

Mnemonic	Description	Value
PG	Relative price of government goods	1.09470
PG.EQ	Equilibrium relative price of government goods	1.09470
PGD	Equilibrium relative price of domestic government goods	1.06000
PGD.EQ	Equilibrium relative price of domestic government goods (cals. from *pg_py.eq*)	1.06000
PGDADJ	*pgd* adjustment cost	0.00000
PGM	Relative price of imported government goods	1.06793
PGM.EQ	Equilibrium relative price of imported government goods	1.06793
PGMADJ	*pgm* adjustment cost	0.00000
PGROW	World price of imported government goods	1.09655
PG_PY.EQ	Equilibrium price of government goods relative to *py* (calibrates *pg.eq*)	0.96000
PI.EQ	Equilibrium relative price of capital goods	0.80392
PK	Relative price of investment goods	0.80392
PK.EQ	Equilibrium relative price of investment goods	0.80392
PK.SS	Steady-state relative price of investment goods	0.80392
PKD	Relative price of domestic investment goods	0.75000
PKD.EQ	Equilibrium relative price of domestic investment goods	0.75000
PKDADJ	*pkd* adjustment cost	0.00000
PKM	Relative price of imported investment goods	0.74068
PKM.EQ	Equilibrium relative price of imported investment goods	0.74068
PKMADJ	*pkm* adjustment cost	0.00000
PKROW	World price of imported investment goods	0.76053
PK_PY.EQ	Equilibrium price of investment relative to *py*	0.70500
PM	Relative price of import goods	0.92030
PM.EQ	Equilibrium relative price of import goods	0.92030
PM_PY.EQ	Equilibrium price of import goods relative to *py*	0.80707
PX	Relative price of export goods	0.99857
PX.EQ	Equilibrium relative price of export goods	0.99857
PXADJ	*px* adjustment cost	0.00000
PXM	Relative price of imported export goods	0.92030
PXM.EQ	Equilibrium relative price of imported export goods	0.92030
PXROW	World price of export goods	1.02533
PX_PY.EQ	Equilibrium price of export goods relative to *py* (calibrates *pxrow.eq*)	0.87570
PY	Relative price of output	1.14031
PY.EQ	Equilibrium relative price of output at market prices	1.14031
PYDOT	Inflation rate for *PY*	0.00249
QDOT	Trend growth in labour augmenting technical progress	0.00325
R	Real interest rate	0.00705
R.EQ	Equilibrium real interest rate	0.00705

Table 2: Endogenous variables

Mnemonic	Description	Value
R5	5-year moving average of real rates	0.00831
R5.EQ	Equilibrium 5-year moving average of real rates	0.00831
RCON.EQ	Equilibrium real interest rate for consumers	0.01823
RGB	Real interest rate for government assets	0.01198
RGB.EQ	Equilibrium real return on government bonds	0.01198
RISK	Transfer to individuals from asset holders	0.03747
RISK.EQ	Equilibrium transfer to individuals from asset holders	0.03747
RK.EQ	Equilibrium real interest rate for capital	0.05354
RL	Real long interest rate	0.00831
RL.EQ	Equilibrium real long interest rate	0.00831
RN	Nominal interest rate	0.00956
RN.EQ	Equilibrium nominal interest rate	0.00956
RN5	5-year moving average of nominal rates	0.01082
RN5.EQ	Equilibrium 5-year moving average of nominal rates	0.01082
RNFA	Real interest rate for net foreign assets	0.01300
RNFA.EQ	Equilibrium real return on net foreign assets	0.01300
RNL	Nominal long interest rate	0.01082
RNL.EQ	Equilibrium nominal long interest rate	0.01082
RROW	Real interest rate in the rest of the world	0.00705
RSL	Slope of the yield curve	-0.00125
RSL.EQ	Equilibrium slope of the yield curve	-0.00125
TD	Net direct tax rate	0.28144
TD.EQ	Equilibrium net direct tax rate	0.28144
TFP	Total factor productivity	0.94777
TFP.EQ	Equilibrium level of total factor productivity (calibrated from y)	0.94777
TIC	Indirect tax rate on consumption goods	0.16540
TICM	Tariff rate on imported consumption goods	0.00000
TIG	Indirect tax rate on government goods	0.03000
TIGM	Tariff rate on imported government goods	0.00000
TII	Indirect tax rate on investment goods	0.08000
TIIM	Tariff rate on imported investment goods	0.00000
TK	Tax rate on profits	0.07500
TWFL.EQ	Equilibrium total wealth	6.49109
U	Rate of unemployment	0.08000
UADJ	u adjustment cost	0.00000
W	Relative wage	0.17991
W.EQ	Equilibrium relative wage	0.17991
WADJ	w adjustment cost	-0.00000

Table 2: Endogenous variables

Mnemonic	Description	Value
WC	Consumer real wage	0.15367
WC.EQ	Equilibrium consumer real wage	0.15367
WP	Producer real wage	0.17802
WP.EQ	Equilibrium producer real wage	0.17802
X	Exports	0.10088
X.EQ	Equilibrium exports	0.10088
XADJ	*x* adjustment cost	0.00000
XM	Imports for re-export	0.03523
XM.EQ	Equilibrium imports for re-export	0.03523
XM_X	Share of imports for re-export	0.34921
Y	Output	0.25000
Y.EQ	Equilibrium output (calibrates *tfp.eq*)	0.25000
YDFL	Real disposable income for forward-looking consumers	0.08941
YDFL.EQ	Equilibrium disposable income for forward-looking consumers	0.08941
YDOT	Trend output growth rate	0.00561
YDOT.EQ	Equilibrium output growth rate	0.00561
YDRT	Real disposable income for rule-of-thumb consumers	0.05960
YDRT.EQ	Equilibrium disposable income for rule-of-thumb consumers	0.05960
YLAB	Real labour income	0.16552
YLAB.EQ	Equilibrium real labour income	0.16552
YP	Potential output	0.25000
Z	Real price of foreign exchange	0.97390
Z.EQ	Equilibrium real price of foreign exchange (calibrates *X_Y0)*	0.97390
Z.SS	Steady-state real price of foreign exchange	0.97390
ZE	Expected real price of foreign exchange	0.97390

Table 3: Parameters

Mnemonic	Description	Value
ALPHA	Capital exponent in Cobb-Douglas production function	0.34490
CB1	Discount factor in the consumption adjustment model	0.95000
CD1	Weight on difference 1 in the *cfl* adjustment model	2.00000
CD2	Weight on difference 2 in the *cfl* adjustment model	1.00000
CD3	Weight on difference 3 in the *cfl* adjustment model	0.00000
CD4	Weight on difference 4 in the *cfl* adjustment model	0.00000
CMB1	Discount factor in the consumption import model	0.85000
CMD1	Weight on difference 1 in the *cm_c* adjustment model	2.00000
CMD2	Weight on difference 2 in the *cm_c* adjustment model	1.00000
CMD3	Weight on difference 3 in the *cm_c* adjustment model	0.50000
CMD4	Weight on difference 4 in the *cm_c* adjustment model	0.25000
CMS2	Parameter in equilibrium *cm* share equation	1.00000
CMV1	Coefficient 1 in the VAR in the consumption import model	0.70000
CV1	Coefficient 1 in the VAR in the consumption model	0.10000
CV2	Coefficient 2 in the VAR in the consumption model M	9.00000
CV3	Coefficient 3 in the VAR in the consumption model	0.35000
DEPR	Capital depreciation rate	0.02131
G1	Parameter in the fiscal expenditure reaction function	0.60000
G2	Parameter in the fiscal expenditure reaction function	0.30000
GAMMA	Probability of death for consumers	0.00985
GMB1	Discount factor in the government import model	0.85000
GMD1	Weight on difference 1 in the *gm_g* adjustment model	2.50000
GMD2	Weight on difference 2 in the *gm_g* adjustment model	1.25000
GMD3	Weight on difference 3 in the *gm_g* adjustment model	0.75000
GMD4	Weight on difference 4 in the *gm_g* adjustment model	0.50000
GMS2	Parameter in equilibrium *gm* share equation	1.00000
GMV1	Coefficient 1 in the 2nd VAR in the government import model	0.40000
GTR1	Parameter in the fiscal transfer reaction function	0.50000
GTR2	Parameter in the fiscal transfer reaction function	0.20000
IMB1	Discount factor in the investment import model	0.85000
IMD1	Weight on difference 1 in the *im_i* adjustment model	2.50000
IMD2	Weight on difference 2 in the *im_i* adjustment model	1.25000
IMD3	Weight on difference 3 in the *im_i* adjustment model	0.75000
IMD4	Weight on difference 4 in the *im_i* adjustment model	0.50000
IMS2	Parameter in equilibrium *im* share equation	1.00000
IMV1	Coefficient 1 in the VAR in the investment import model	0.60000
K1	Utility parameter for apportioning *c/i* split of demand shocks	2.50000
KB1	Discount factor in the capital model	0.40000

Table 3: Parameters

Mnemonic	Description	Value
KD1	Weight on difference 1 in the *k* adjustment model	6.00000
KD2	Weight on difference 2 in the *k* adjustment model	4.00000
KD3	Weight on difference 3 in the *k* adjustment model	3.00000
KD4	Weight on difference 4 in the *k* adjustment model	1.00000
KE1	Weight on *k.eq* adjustment term in the *cc.eq* equation	0.55000
KV1	Coefficient 1 in the VAR in the capital model	0.18000
KV2	Coefficient 2 in the VAR in the capital model	1.10000
LAMDA	Proportion of rule-of-thumb consumers in the population	0.40000
PCDB1	Discount factor for the *pcd* adjustment model	0.95000
PCDD1	Weight on difference 1 in the *pcd* adjustment model	0.00000
PCDD2	Weight on difference 2 in the *pcd* adjustment model	0.00000
PCDD3	Weight on difference 3 in the *pcd* adjustment model	0.00000
PCDD4	Weight on difference 4 in the *pcd* adjustment model	0.00000
PCM1	Pass-through coefficient, relative imported consumption *.eq* trade prices	0.80000
PCMB1	Discount factor in the price of consumption imports model	0.95000
PCMD1	Weight on difference 1 in the *pcm* adjustment model	2.00000
PCMD2	Weight on difference 2 in the *pcm* adjustment model	1.00000
PCMD3	Weight on difference 3 in the *pcm* adjustment model	0.00000
PCMD4	Weight on difference 4 in the *pcm* adjustment model	0.00000
PCMV1	Pass-through coefficient, relative imported consumption trade prices	0.50000
PCMV2	Coefficient 2 in the VAR in the *pcm* model	0.80000
PD0	Coefficient on the gap in the inflation equation	0.02000
PD1	Coefficient on lagged gap in the inflation equation	0.04000
PD2	Coefficient on the positive gap in the inflation equation	0.09000
PD3	Coefficient on the lagged positive gap in the inflation equation	0.03000
PD4	Coefficient on wage effects in the inflation equation	2.00000
PD5	Coefficient on wages changes in the inflation equation	0.60000
PD6	Coefficient on wages changes in the inflation equation	0.25000
PD7	Coefficient on wages changes in the inflation equation	0.15000
PDA1	Weight on lagged inflation in the inflation equation	0.35000
PDA2	Weight on second lag of inflation in the inflation equation	0.25000
PDA3	Weight on third lag of inflation in the inflation equation	0.20000
PDA4	Relative weight of producer price expectations	0.60000
PDA5	Coefficient on import price change in the inflation equation	0.05000
PDA6	Coefficient on export price change in the inflation equation	0.05000
PDE0	Weight on the expected target in *P* inflation expectations	0.10000
PDE1	Weight on the lead in *P* inflation expectations	0.55000
PDE2	Weight on the lead in *PC* inflation expectations	0.55000

Table 3: Parameters

Mnemonic	Description	Value
PDE3	Weight on the expected target in *PC* inflation expectations	0.10000
PDE4	Weight on the level gap in inflation expectations	0.00000
PDF1	Weight on trend expectations in the inflation equation	0.25000
PDF2	Weight on expected inflation in the inflation equation	0.43000
PDL1	Weight on lagged *pdot* in the inflation expectations equation	0.70000
PGDB1	Discount factor in the *pgd* model	0.95000
PGDD1	Weight on difference 1 in the *pgd* adjustment model	1.00000
PGDD2	Weight on difference 2 in the *pgd* adjustment model	0.00000
PGDD3	Weight on difference 3 in the *pgd* adjustment model	0.00000
PGDD4	Weight on difference 4 in the *pgd* adjustment model	0.00000
PGDV1	Coefficient 1 in the VAR in the *pgd* model	0.05000
PGM1	Pass-through coefficient, relative imported government *.eq* trade prices	0.80000
PGMB1	Discount factor in the price of government imports model	0.95000
PGMD1	Weight on difference 1 in the *pgm* adjustment model	2.00000
PGMD2	Weight on difference 2 in the *pgm* adjustment model	1.00000
PGMD3	Weight on difference 3 in the *pgm* adjustment model	0.00000
PGMD4	Weight on difference 4 in the *pgm* adjustment model	0.00000
PGMV1	Pass-through coefficient, relative import government trade prices	0.50000
PGMV2	Coefficient 2 in the VAR in the price of government imports model	0.80000
PK1	Parameter in definition of price of capital goods	0.45000
PKDB1	Discount factor in the *pkd* model	0.95000
PKDD1	Weight on difference 1 in the *pkd* adjustment model	1.00000
PKDD2	Weight on difference 2 in the *pkd* adjustment model	0.00000
PKDD3	Weight on difference 3 in the *pkd* adjustment model	0.00000
PKDD4	Weight on difference 4 in the *pkd* adjustment model	0.00000
PKDV1	Coefficient 1 in the VAR in the *pkd* model	0.00000
PKM1	Pass-through coefficient, relative imported investment *.eq* trade prices	0.80000
PKMB1	Discount factor in the price of investment imports model	0.95000
PKMD1	Weight on difference 1 in the *pkm* adjustment model	2.00000
PKMD2	Weight on difference 2 in the *pkm* adjustment model	1.00000
PKMD3	Weight on difference 3 in the *pkm* adjustment model	0.00000
PKMD4	Weight on difference 4 in the *pkm* adjustment model	0.00000
PKMV1	Pass-through coefficient, relative imported investment trade prices	0.50000
PKMV2	Coefficient 2 in the VAR in the *pkm* model	0.80000
PTL1	Weight on lagged *pdottar* in the *pdottar* expectations equation	1.35000
PTL2	Weight on 2nd lagged *pdottar* in the *pdottar* expectations equation	-0.42500
PTL3	Weight on forward *pdot* in the *pdottar* expectations equation	1.00000
PX1	Pass-through coefficient, relative export *.eq* trade prices	0.75000

Table 3: Parameters

Mnemonic	Description	Value
PXB1	Discount factor in the price of exports model	0.95000
PXD1	Weight on difference 1 in the *px* adjustment model	0.80000
PXD2	Weight on difference 2 in the *px* adjustment model	0.50000
PXD3	Weight on difference 3 in the *px* adjustment model	0.00000
PXD4	Weight on difference 4 in the *px* adjustment model	0.00000
PXV1	Pass-through coefficient, relative export trade prices	0.50000
PXV2	Coefficient 2 in the VAR for the price of exports	0.00000
PXV3	Coefficient 3 in the VAR for the price of exports	0.10000
RI1	Parameter in the risk equation	0.95000
RL1	Weight on the short rate in the *rl* equation	0.30000
RL2	Weight on the *r5* rate in the *rl* equation	0.50000
RSL0	Coefficient on inflation gap, lead 0, monetary reaction function	0.00000
RSL1	Coefficient on inflation gap, lead 1, monetary reaction function	0.00000
RSL2	Coefficient on inflation gap, lead 2, monetary reaction function	0.00000
RSL3	Coefficient on inflation gap, lead 3, monetary reaction function	0.00000
RSL4	Coefficient on inflation gap, lead 4, monetary reaction function	0.00000
RSL5	Coefficient on inflation gap, lead 5, monetary reaction function	0.00000
RSL6	Coefficient on inflation gap, lead 6, monetary reaction function	0.00000
RSL7	Coefficient on inflation gap, lead 7, monetary reaction function	1.57500
RSL8	Coefficient on inflation gap, lead 8, monetary reaction function	1.80000
RSL9	Coefficient on inflation gap, lead 9, monetary reaction function	0.00000
RSL10	Coefficient on inflation gap, lead 10, monetary reaction function	0.00000
RSL11	Coefficient on inflation gap, lead 11, monetary reaction function	0.00000
RSL12	Coefficient on inflation gap, lead 12, monetary reaction function	0.00000
RSL13	Coefficient on price level gap, monetary reaction function	0.00000
SIGMA	Coefficient of intertemporal substitution for forward-looking consumers	0.66000
TD0	Parameter in the fiscal tax reaction function	0.40000
TD1	Parameter in the fiscal tax reaction function	0.250000
TD3	Parameter in the fiscal tax reaction function	0.80000
UB1	Discount factor in the unemployment model	0.95000
UD1	Weight on difference 1 in the *u* adjustment model	1.00000
UD2	Weight on difference 2 in the *u* adjustment model	0.50000
UD3	Weight on difference 3 in the *u* adjustment model	0.00000
UD4	Weight on difference 4 in the *u* adjustment model	0.00000
UV1	Coefficient on the wage gap in the unemployment equation	0.06700
UV2	Coefficient on *ygap*(-2) in the unemployment equation	0.22500
UV3	Coefficient on *ygap*(-3) in the unemployment equation	0.22500
WB1	Discount factor in the real wage model	0.95000

Table 3: Parameters

Mnemonic	Description	Value
WD1	Weight on difference 1 in the *w* adjustment model	1.50000
WD2	Weight on difference 2 in the *w* adjustment model	1.00000
WD3	Weight on difference 3 in the *w* adjustment model	0.75000
WD4	Weight on difference 4 in the *w* adjustment model	0.50000
WV1	Coefficient 1 in the VAR in the real wage model	0.25000
WV2	Coefficient 2 in the VAR in the real wage model	1.00000
WV3	Coefficient 3 in the VAR in the real wage model	1.00000
X2	Parameter in equilibrium export equation	1.00000
XB1	Discount factor in the export model	0.65000
XD1	Weight on difference 1 in the *x* adjustment model	5.00000
XD2	Weight on difference 2 in the *x* adjustment model	2.00000
XD3	Weight on difference 3 in the *x* adjustment model	0.00000
XD4	Weight on difference 4 in the *x* adjustment model	0.00000
XV1	Coefficient 1 in the VAR in the export model	1.40000
YD1	Proportion of transfers to forward-looking consumers taxable	0.50000
YD2	Proportion of transfers to rule-of-thumb consumers taxable	0.50000
YGAP0	Coefficient on output gap, lead 0, monetary reaction function	0.00000
Z1	Weight on the lag in exchange rate equation	0.38000
Z2	Weight on the uncovered-interest-parity term in exchange rate equation	0.52000
ZETA	Coefficient on *fa.ss* gap in *c.eq* for forward-looking consumers	0.20000
ZF1	Weight on the lead in exchange rate expectations	0.60000
ZL1	Weight on the lag in exchange rate expectations	0.40000

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