New Keynesian, Open-Economy Models and Their Implications for Monetary Policy*

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Introduction

Although there were some clear antecedents, including most notably Svensson and van Wijnbergen (1989), the publication of Obstfeld and Rogoff's (1995a) "Exchange Rate Dynamics Redux" marked the beginning of a surge in work on a new class of open-economy macroeconomic models. A few key features distinguish this class of models:

- optimization-based dynamic general-equilibrium modelling;
- sticky prices and/or wages in at least some sectors of the economy;
- incorporation of stochastic shocks;
- evaluation of monetary policies based explicitly on household welfare.

This paper summarizes some of the work in this field, emphasizing its implications for monetary policy. New Keynesian, open-economy models have not yet solved long-standing debates, but they have clarified a number of important issues. Because the work incorporates sticky prices or wages into optimization-based general-equilibrium models, this literature holds the

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promise of combining some of the internally consistent long-run properties of international real-business-cycle models with short-run Keynesian features that allow for a discussion of monetary policy and its effects on aggregate demand. By incorporating stochastic shocks, these models are able to address the effects of risk on prices, wages, trade flows, and capital flows and the ways that monetary policy affects these risks. Perhaps most importantly, evaluation of policy based on household welfare has provided a new perspective on the analysis of the impacts of the transmission of shocks across countries and exchange rate pass-through on optimal monetary policy rules and international policy coordination. However, while there have been new conceptual insights from this literature, there has been considerably less work on empirical estimation or testing of these new models. Furthermore, the literature is not yet at the stage where it can confidently make quantitative suggestions as to how monetary policy should operate in an open economy.

The remainder of the paper is divided into four sections. The first briefly outlines the original Redux model and its implications. The second section discusses a few of the many extensions that have been made to the Redux model in the years since its publication. It focuses on the extensions we believe are qualitatively most important for understanding optimal monetary policy in an open economy. The third examines the implications of this literature for optimal monetary policy for a single country. The fourth section examines the implications for optimal monetary coordination across countries, and conclusions follow.

1 Exchange Rate Dynamics Redux

Obstfeld and Rogoff (1995a) introduce a two-country model with a continuum of differentiated traded goods; a fraction n of the goods is produced domestically, and the remaining fraction, $1-n$, is produced abroad. Domestic and foreign households and governments are modelled as having identical preferences over an index of all the differentiated goods (indexed by z) produced in the world:

$$C = \left[\int_0^1 c(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \qquad G = \left[\int_0^1 g(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

where $c(z)$ represents the household's consumption of good z, and $g(z)$ represents the government's consumption. (Throughout, foreign counterparts to domestic variables will be designated by an asterisk, $(*)$; for example, foreign consumption of good z is $c^*(z)$, and the foreign consumption index is C^*.)

Obstfeld and Rogoff assume that the law of one price holds for every good:

$$p(z) = ep^*(z), \tag{2}$$

where $p(z)$ ($p^*(z)$) is the price of good z in domestic (foreign) currency, and e is the exchange rate. The price index associated with preferences of form (1) is:

$$P = \left[\int_0^1 p(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}}$$

$$= \left[\int_0^n p(z)^{1-\theta} dz + \int_n^1 ep^*(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}}. \tag{3}$$

Formally, each household is modelled as producing its own individual good with its own labour; however, this is equivalent to assuming that labour is purchased competitively at a market-clearing flexible wage. While the labour market is competitive and the wage is flexible, each firm is a monopolistic competitor and prices are set one period in advance in the producer's currency. Equation (1) implies a constant elasticity of demand for each good and, as a result, each firm would set its price at a constant markup over marginal cost if prices were flexible. Assuming that κ units of labour are required to produce one unit of a good, the firm's desired price is:

$$p(z) = \left(\frac{\theta}{\theta - 1}\right)\kappa w. \tag{4}$$

Redux analyzes a perfect foresight setting and then introduces a one-time unforeseen policy shock. In the model, there is an integrated world capital market where agents may buy or sell risk-free indexed debt, yielding a real interest rate, r, in terms of the common basket of goods. Because this is a perfect foresight model and because the law of one price holds for all goods, real interest rate equalization across countries implies that uncovered interest rate parity holds both ex ante and ex post,

$$1 + i_t = \frac{e_{t+1}}{e_t}(1 + i_t^*), \tag{5}$$

where i_t is the nominal interest rate. Households act to maximize a utility function of the form

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t}\left[\frac{1}{1-\rho}C_s^{1-\rho} + \frac{\chi}{1-\varepsilon}\left(\frac{M_s}{P_s}\right)^{1-\varepsilon} - \frac{\kappa}{\nu}y_s(z)^{\nu}\right], \tag{6}$$

where M represents holdings of money and $y(z)$ can be interpreted either directly as output or indirectly as the amount of labour the household supplies. The first-order conditions for utility maximization imply that the household will choose consumption and money holdings so that

$$C_{t+1} = [\beta(1+r_t)]^{\frac{1}{\rho}}C_t, \tag{7}$$

$$\frac{M_t}{P_t} = \left[\chi C_t^{\rho}\left(\frac{1+i_t}{i_t}\right)\right]^{\frac{1}{\varepsilon}}. \tag{8}$$

A positive monetary shock to the home country will have some of the same effects found in the standard Mundell-Fleming model: the shock will lead domestic households to increase their aggregate consumption demand and will lead to a depreciation of the exchange rate and an increase in net domestic claims on foreigners. Perhaps surprisingly, though, all of these effects are largely permanent. Equation (7) implies that, all else given, households will raise not only current consumption but also all future consumption by using some of the current income increase to increase asset holdings. Although the real interest rate may move to offset some of this effect, changes to relative consumption demand (C/C^*) will be permanent because domestic and foreign households face the same real interest rate. For the same reasons, the model implies that there is no exchange rate overshooting in response to a permanent monetary shock—as just argued, relative consumption will immediately jump to its new level for any shock and by definition a permanent money shock will cause the relative money supply to immediately jump to its new level, hence the exchange rate and relative money demand will also immediately jump to the new equilibrium levels.

As these examples show, explicit modelling of general-equilibrium dynamics leads to some conclusions about the effects of policy that differ from the conclusions in older Keynesian models, while still allowing for many Keynesian effects. There are also some surprising conclusions from the explicit modelling of welfare-maximizing agents: although it might appear that a permanent domestic money shock leaves domestic agents better off and foreign agents worse off, Obstfeld and Rogoff show in the Redux model that domestic and foreign agents experience the same welfare gain. The gain from increasing output follows from the monopoly power of

firms. Because of this market power, output is suboptimally low; the welfare gain to agents from a monetary increase comes from the expansion of output it causes, which pushes output closer to its optimal level. Because domestic and foreign agents are affected to the same degree by this market imperfection, both gain equally by its reduction.

2 Extensions

Lane (2001) and Sarno (2001) survey many of the extensions to the original Redux model.[1] Here we focus on the extensions that we believe have the most important qualitative implications for the conduct of monetary policy in an open economy. We divide these extensions into those having to do with intratemporal (static) decisions and those associated with intertemporal (dynamic) decisions.

2.1 Static extensions

2.1.1 Preferences between domestic and foreign goods

Warnock (1998) introduces home bias into the Redux framework by assuming that domestically produced goods receive greater weight in the consumption indexes of domestic agents. Home bias results in a domestic monetary shock having a greater effect on domestic welfare than foreign welfare, because domestic agents benefit more from the expansion of domestic output. The exchange rate will also overshoot in response to a permanent monetary shock, because home bias allows the real exchange rate to be affected by shifts in wealth across countries and hence for differences in the real interest rate as measured in domestic and foreign baskets of consumption goods. An appendix to the Redux model introduces non-traded goods, as do Hau (2000) and Obstfeld and Rogoff (2000, 2002). This is an alternative to the form of home bias studied by Warnock that similarly allows for deviations from purchasing-power parity because tastes are no longer identical and because the law of one price will not hold for non-traded goods.

Several papers relax the Redux assumption that the elasticity of substitution between domestic and foreign goods is identical to the elasticity of substitution between different domestic goods. These papers include Corsetti and Pesenti (2001a); Chari, Kehoe, and McGrattan (1998); and Tille (2001). These papers model the consumption index as:

1. For more papers in the "new open-economy macroeconomics" literature, see Brian Doyle's Web site on the topic at http://www.geocities.com/brian_m_doyle/open.html.

$$C = \left[\gamma C_h^{\frac{\varphi-1}{\varphi}} + (1-\gamma) C_f^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}}, \tag{9}$$

where

$$C_h = \left[\int_0^n c(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \qquad C_f = \left[\int_n^1 c(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}, \tag{10}$$

so that the elasticity of substitution between domestic and foreign goods is φ, while the elasticity of substitution between domestic goods is θ. Tille (2001) shows that an unexpected monetary expansion still improves home welfare relative to foreign welfare if the elasticity of substitution between home and foreign goods is larger than the elasticity of substitution of goods within the home and foreign economies. Home welfare relative to foreign welfare is reduced when the opposite is true. Only in the case where they are equal do home and foreign benefit equally. If the gap between the two elasticities is large enough, then a home monetary expansion will have a "beggar-thy-neighbour" effect on foreign welfare, reducing its absolute welfare. Likewise, monetary policy may even have a "beggar-thyself" effect if the gap the other way is large enough.

Corsetti and Pesenti (2001a) analyze what has become a particularly important case. Setting $\varphi = 1$ yields a Cobb-Douglas form for the consumption index:

$$C = C_h^{\gamma} C_f^{1-\gamma}. \tag{11}$$

A unit elasticity of substitution implies that total household expenditures on domestic and foreign goods are constant. Because a rise in the foreign price of domestic goods will result in a proportionate decrease in the quantity of foreign demand for domestic goods, export revenue remains constant. The importance is that if the current account begins in balance, it will remain so.[2] As a result, the permanent effects on the current account that Obstfeld and Rogoff emphasize in the Redux model will not occur. This property allows Corsetti and Pesenti to solve the model in closed form, without the need for linear approximation. Another implication of this assumption is that in equilibrium, foreign and domestic consumption of traded goods will be perfectly correlated because the unitary elasticity of demand protects

2. This same feature was emphasized by Cole and Obstfeld (1991) and Newberry and Stiglitz (1984).

revenue from shocks. If utility is separable between traded consumption and the other variables that affect welfare, then the fact that traded consumption is perfectly correlated means that agents do not require securities markets to share risk; risk-sharing automatically occurs in this case. If utility is non-separable in traded consumption, then risk-sharing will not usually imply perfect correlation between cross-country tradables consumption, because the marginal utility of tradables consumption will fluctuate with movements in the other variables affecting welfare. This condition implies that the ratio of domestic to foreign tradables consumption should fluctuate as well, unless shocks are global and have common effects across sectors.

2.1.2 Pass-through from exchange rates to domestic prices

The Redux model assumes that the law of one price holds for all goods. Aggregating across goods implies purchasing-power parity,

$$P = eP^*. \tag{12}$$

As is well known, most exchange rates exhibit substantial and long-lasting deviations from purchasing-power parity. Although the introduction of non-traded goods would allow for deviations from purchasing-power parity, as documented by Engel (1999) and Rogers and Jenkins (1995), deviations from the law of one price for traded goods appear to explain the majority of fluctuations in real exchange rates. This evidence has led a number of authors to explore alternative pricing structures. The Redux model assumed that firms set prices in the sellers' currency, what has come to be called producer currency pricing (PCP). Betts and Devereux (1996, 2000a, 2000b) introduce the alternative assumption that a fraction of firms set prices in the buyers' currency or local currency pricing (LCP). Devereux and Engel (1998, 2000); Kollmann (2001); Chari, Kehoe, and McGrattan (1998); and Bergin and Feenstra (2001) have all incorporated the LCP assumption in their work. Letting s represent the fraction of foreign firms who set prices in domestic currency and using $\bar{p}$ to indicate that a price is fixed, Betts and Devereux's formulation alters equation (3) to have the form

$$P = \left[\int_0^n \bar{p}(z)^{1-\theta} dz + \int_n^{n+(1-n)s} \bar{p}^*(z)^{1-\theta} dz + \int_{n+(1-n)s}^1 e\bar{p}^*(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}. \tag{13}$$

Corsetti and Pesenti (2001b) alternatively model deviations from the law of one price by assuming that foreign firms are able to respond to a fraction of exchange rate movements, which in this framework alters the form of the domestic price index to:

$$P = \left[\int_0^n \bar{p}(z)^{1-\theta} dz + \int_n^1 (e^{1-s} \bar{p}^*(z))^{1-\theta} dz \right]^{\frac{1}{1-\theta}}. \quad (14)$$

To understand the differences in implication, it is useful to compare full PCP $(s = 0)$ with full LCP $(s = 1)$. In the Redux model, there is full pass-through of exchange rate movements to import prices. With full PCP, movements in the exchange rate will affect the consumer price index. Taking a log approximation (where a hat (^) over a variable indicates log deviation from steady state) to equation (3) yields

$$\hat{P} = (1 - n)\hat{e}, \quad (15)$$

implying that a 1 per cent movement in the exchange rate will have an effect on consumer prices equal to the share of imports in consumption. A rise in the exchange rate will shift demand towards domestic goods and away from imports by raising the relative price of imports. On the other hand, with full LCP there is no pass-through from the exchange rate to import prices, and equations (13) and (14) imply that the price level is completely unaffected by exchange rate movements in the short run. In this world, exchange rate movements will not shift relative demand for imports and will not act to equilibrate demand in response to economic disturbances.

Local currency pricing is able to capture several key empirical features. The assumption of full LCP implies that short-term movements in the nominal and real exchange rate will be perfectly correlated, which is similar to the evidence presented in Mussa (1986); there is little or no short-term pass-through from exchange rates to consumer prices, which is similar to evidence for the United States; and full or partial LCP will tend to produce greater variability in the nominal exchange rate, because larger movements in the exchange rate are required to affect the relative price of imports and equilibrate changes in import demand. However, as emphasized by Obstfeld (2001), the LCP assumption implies that when a country's exchange rate depreciates, its terms of trade should improve (import prices are unaffected and export prices, which are fixed in terms of the foreign currency, will rise in terms of the domestic currency), which is counter to the empirical evidence (Obstfeld and Rogoff 2000). By failing to differentiate between consumer prices and wholesale or intermediate prices, the LCP literature cited above effectively discounts the economic importance of significant pass-through of exchange rate movements to wholesale import prices. In a survey of the evidence, Goldberg and Knetter (1997) conclude that roughly half of exchange rate movements are passed on to U.S. wholesale import

prices within one year, which is a considerably larger short-term effect than found for consumer price indexes.

In response to this type of evidence, a number of authors have recently begun to model richer environments in which wholesale import prices differ from consumer prices in economically important ways. Burstein, Neves, and Rebelo (2000); Burstein, Eichenbaum, and Rebelo (2002); McCallum and Nelson (1999, 2000); and Corsetti and Dedola (2002) all consider environments in which the marketing and distribution of imported goods require the use of non-traded goods as an input. Obstfeld (2001) and Engel (2002) consider environments in which firms combine domestically produced intermediate goods with imported intermediates, employing PCP to produce a non-traded consumption good. If the price of the consumption good is sticky, then exchange rate changes will have no impact on consumer prices, but will affect the terms of trade and induce firms to switch demand between domestic and imported intermediate goods.

Several recent papers have begun to consider the endogeneity of the currency pricing choice as well. Devereux and Engel (2001) show that under complete risk-sharing, all firms will denominate their sales in the most stable currency regardless of whether it is domestic or foreign. With incomplete risk-sharing, they conclude that LCP may be an equilibrium outcome, but that PCP is not a robust outcome. Bacchetta and van Wincoop (2002) conclude that PCP may be an equilibrium outcome if domestic firms have a high market share in foreign markets and the elasticity of substitution between sectors is low. Corsetti and Pesenti (2002) analyze the possibility of multiple equilibria. If exchange rate variability is low, then LCP is more attractive to firms, and if firms practice LCP, then monetary authorities may have an incentive to keep exchange rate variability low (see section 3). Conversely, if exchange rate variability is high, then firms have an incentive to practice PCP, and in this case monetary authorities are more likely to choose a flexible exchange rate regime.

2.1.3 Wage stickiness versus price stickiness

While the Redux paper assumes effectively that nominal wages are perfectly flexible and output prices are sticky, other papers have reversed the two, making wages sticky and prices perfectly flexible.[3] Household utility (equation (6)) now depends negatively on work effort, where each household has differentiated labour—L replaces $y(z)$, and k is the marginal disutility of effort. Each household supplies labour to each firm at a wage set

3. Among those doing so in this literature were Obstfeld and Rogoff (1996, chapter 10), Corsetti and Pesenti (2002), and Obstfeld and Rogoff (2000).

one period in advance. The corresponding aggregate nominal wage is an index of the nominal wages of each worker,

$$W = \left[\int_0^1 W(i)^{1-\phi} di\right]^{\frac{1}{1-\phi}}. \tag{16}$$

If each firm has a production function,

$$y(z) = \left[\int_0^1 L(z,i)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \tag{17}$$

which produces a differentiated good, then prices will be a constant markup over wages, as in equation (4). Perfectly competitive output markets, when $\theta \to \infty$, will mean that prices move one-for-one with nominal wages.

Corsetti and Pesenti (2002) and Obstfeld and Rogoff (2000) argue that sticky wages and flexible prices are closer to reality. Despite this point, if prices are set as a constant markup over marginal cost, then for certain applications it may not matter whether prices or wages are sticky. Erceg, Henderson, and Levin (2000) show one example of when it does matter—in a closed economy with both staggered price- and staggered wage-setting, the monetary authority can no longer replicate the flexible price equilibrium.

2.2 Dynamic extensions

As emphasized in the Redux model, consumption smoothing will tend to lead to permanent effects, even of monetary shocks. These permanent effects imply that the steady state of the model will move in response to shocks, making linearizing around a fixed steady state a dubious proposition. By fixing prices for one period only and examining the perfect foresight solution with a single unexpected shock to policy, Obstfeld and Rogoff were able to properly take into account the change in steady-state values. However, while the assumptions that prices were fixed for only one period and that shocks were unexpected make the model more analytically tractable, they do not lead to very satisfying dynamics.

Other papers have relaxed the assumption of perfect foresight or allowed for richer dynamic structures, but have needed in turn to confront the issue that wealth effects of consumption smoothing can cause changes in the steady state. Most papers have chosen to make assumptions that effectively shut down this channel by assuming that financial markets are complete or that preferences are such that the equilibrium mimics complete financial

markets, as discussed in section 2.1.1. A few papers have recently made alternative assumptions that allow for transitory shifts in net foreign assets while still guaranteeing a unique long-run steady state. This later approach is promising; however, it is important to note that it may not be economically significant in terms of the accuracy of existing model solution procedures whether relative consumption levels have an exact unit root (which implies there is no unique steady state) or a near unit root (which implies that there is a unique steady state but that equilibrium values may wander very far from it). Merely guaranteeing a unique steady state may not guarantee that current solution procedures are accurate.

2.2.1 Stochastic shocks

Several authors have analyzed monetary shocks within a stochastic framework (for example, Obstfeld and Rogoff (1998, 2000), Bacchetta and van Wincoop (2000), and Devereux and Engel (1998)). In these papers, monetary shocks only have real effects for one period, since wages are pre-set for one period, and the models use the Corsetti and Pesenti assumptions of a zero initial current account and a unitary elasticity of substitution between home and foreign tradables. Households now maximize expected utility in the face of monetary shocks[4] and disutility of effort shocks. All shocks to the model are assumed to be lognormally distributed.[5] Obstfeld and Rogoff (1998) need only linearize the money market equilibrium around the non-stochastic steady state with a constant growth rate in consumption and the money supply. Others assume that household utility is logarithmic in real money balances in order to obtain closed-form solutions.

In this framework, the volatility of variables can affect welfare and first moments of endogenous variables, including the exchange rate, terms of trade, consumption, and price-setting. If workers set their wages one period in advance, they will set their wages such that the expected marginal utility of the consumption an extra hour of labour can buy equals the expected marginal disutility of providing the extra hour of labour.

$$W = \left(\frac{\phi}{\phi - 1}\right)\frac{E(\kappa L)^{\nu}}{E(LP^{-1}C^{-\rho})} \tag{18}$$

4. In these papers, the money supplies at home and abroad follow a random walk, $m_t = m_{t-1} + \mu_t$, where μ_t is normally distributed with mean zero and variance $\sigma_\mu{}^2$.

5. Remember that if x is normally distributed with mean μ and standard deviation σ, then $E(e^{xy}) = e^{y\mu + \frac{y^2}{2}\sigma^2}$.

Making use of the assumption that all endogenous variables are lognormal (since all shocks are), the nominal wage can be rewritten in terms of the means, variances, and covariances:

$$W = \left(\frac{\phi}{\phi - 1}\right)\frac{E(\kappa)(E(L))^{\nu-1}}{E(P^{-1})(E(C))^{-\rho}}\exp^{\left(\frac{\nu(\nu-1)}{2}\sigma_t^2 - \frac{\rho(\rho+1)}{2}\sigma_c^2 + \nu\sigma_{\kappa l} + \rho\sigma_{cl} - \rho\sigma_{cp} + \nu\sigma_{lp}\right)}. \quad (19)$$

Since households set their wages one period in advance, not only do the expected values of variables influence their decisions, but variances do as well. For example, since workers like consumption and dislike work effort, high levels of consumption at the same time they are required to work more, a positive σ_{cl}, will imply that they will raise their wages to reduce their expected workload. A higher disutility of effort at the same time when workers must provide more labour, a positive σ_{kl}, also means that workers will raise their pre-set wages.

In a stochastic framework with nominal rigidities, the variance as well as the level of monetary policy shocks can therefore also have an effect on the level of variables in the economy, and more importantly its ex ante welfare. While some might question the relevance of looking at monetary policy shocks to implement monetary policy, it will be important when we look at monetary policy rules. Under floating exchange rates and in the absence of other shocks, the more variable monetary policy, the more variable the nominal exchange rate and the higher the variability of consumption, which results in a reduction of welfare. Higher monetary volatility further reduces welfare by increasing pre-set wages, moving the economy farther away from the competitive level, thereby reducing the level of consumption. Devereux and Engel (1998) show that this reduction in the level of consumption—resulting from an increase in monetary policy's variance—also holds true under LCP, even though there is no longer any effect on the variance of consumption. Monetary volatility will also have an effect on the level of exchange rate, but, surprisingly, higher monetary volatility will reduce, not raise, the risk premium. Obstfeld and Rogoff (1998) point out that this result may help explain part of the "forward premium puzzle." Bacchetta and van Wincoop (1998, 2000) show in a model with LCP and non-separable preferences between consumption and leisure, that nominal exchange rate volatility does not necessarily have a negative effect on trade flows and likely has a negative effect on capital flows. Furthermore, the welfare effects of exchange volatility diminish the larger a country is as a percentage of the world economy—since most goods are produced at home and their prices are set. Obstfeld and Rogoff (1998) show through a simple illustration that the size of the welfare effect of a reduction in exchange rate volatility, holding all else constant (including the variance of monetary policy shocks), may be quite large—1 per cent of GDP per year, in their case.

Despite theoretical work that shows a link between exchange rate uncertainty and both prices and real macroeconomic variables, earlier empirical work is mixed. Papers that look for direct links between volatility and economic variables do not find much of a relationship. A sizable literature that estimates the trade-suppressing effect of nominal exchange rate volatility has found small and usually insignificant results,[6] consistent with Bacchetta and van Wincoop (2000). Baxter and Stockman (1989) and Flood and Rose (1995) found little or no relationship between exchange rate volatility and a wide number of other real macroeconomic variables. Work that has focused instead on differences in regimes has been more successful in finding sizable changes in variables, but at the cost of being less able to point directly at the cause. McCallum (1995) and others show that trade within borders, where nominal exchange rate volatility is zero and real exchange rate variability low, is significantly higher than trade across borders. Rose (2002) summarizes a now large body of work that shows much higher trade flows between countries within a currency union than countries not part of such a union. Output in nations belonging to currency unions is higher as well. A recent paper by Broda (2002) finds that, over the period 1980 to 1996, national price levels[7] are about 20 per cent higher in countries that he classifies as having fixed exchange rates as compared with those with floating exchange rates. As in the earlier papers, however, he finds a weak relationship between national price levels and the choice of a fixed or flexible exchange rate in developed countries. Further work in light of these recent studies may yield additional positive evidence.

2.2.2 Asset markets

The original Redux model assumed that the only financial assets available to households were money and a risk-free indexed bond. Because of the resulting market incompleteness, the model implied that even monetary shocks could shift wealth across countries via movements in the current account, leading to permanent effects on the equilibrium of the model and on welfare. In subsequent work, several authors have assumed instead that financial markets are complete, including Chari, Kehoe, and McGrattan (1998); Devereux and Engel (2000); and Engel (2002). This assumption shuts down one potential source of distortion to the economy, leaving only the distortions from sticky prices and the market power of the firm in the original Redux model. It also shuts down any effects on the current account in that model. Intuitively, this occurs because agents will trade assets in such a way as to avoid shifts in wealth due to monetary shocks. Alternatively,

6. Surveyed by Côté (1994) and McKenzie (1999).
7. Defined as the ratio of a currency's purchasing-power-parity value to its market value.

with complete asset markets, agents have no need to borrow or lend in international spot markets for capital, because they can hold an asset portfolio that allows them to receive their desired stream of income in any given state of nature. The assumption of complete markets has a practical advantage of making the model easier to solve, since current account movements impart dynamics to the original Redux model that made a closed-form solution impossible. Although market completeness clearly affects the qualitative implications of these models—with market incompleteness implying that monetary shocks may permanently affect relative consumption levels across countries—Chari, Kehoe, and McGrattan (1998) and Betts and Devereux (2001) conclude that when they considered monetary shocks, the quantitative effect of complete versus incomplete markets is small in their calibrations. (Betts and Devereux conclude that financial market completeness does matter when considering fiscal policy shocks.) Of course, as discussed above, if there is a unitary elasticity of demand between domestic and foreign traded goods, it is irrelevant whether markets are complete, since the equilibrium will coincide with the complete markets outcome regardless of what or how many assets are actually traded.

2.2.3 Current account dynamics

The intertemporal approach to the current account gained popularity within academic circles in the early 1980s.[8] The approach was an extension of the permanent income hypothesis to an open-economy setting. It viewed the current account as a means through which domestic residents attempt to smooth their consumption by borrowing from or lending to the rest of the world. In our current framework, using a stochastic version of equation (7) and assuming a constant interest rate,

$$r = 1 - \frac{1}{\beta}$$

implies a constant path for expected consumption:

$$C_t = E_t(C_{t+1}). \tag{20}$$

The focus on the intertemporal choice to borrow or lend from abroad reduced emphasis on intratemporal competitiveness, as measured by the real exchange rate, and instead emphasized households' expectations of future income. Indeed, the existing empirical literature on the intertemporal approach has assumed that there is a single aggregate good for which the

8. See Buiter (1981), Obstfeld (1982), Sachs (1981), and Svensson and Razin (1983). Obstfeld and Rogoff (1995b) provide a comprehensive survey.

law of one price holds, so that the real exchange rate does not even enter the equations.[9] The original Redux model held out the promise of reincorporating some of these effects into intertemporal models of current account behaviour. However, as noted above, much of the subsequent work has made assumptions on either asset structure or preferences that have the effect of shutting down current account dynamics.

Are current account dynamics important for understanding monetary policy or the economy more generally? Central banks and international institutions such as the IMF often worry about current account balances when they fall substantially into deficit. The assumption of complete markets allows for linearizing models around a zero current account balance. However, if markets are incomplete, any variety of monetary or non-monetary shocks may eventually drive current account balances away from zero, and as emphasized by Benigno (2001a), solutions around non-zero current account balances can have materially different implications for the effects of monetary policy. Lane and Milesi-Ferretti (2002a,b) empirically link net foreign asset positions to long-run values of the real exchange rate, suggesting that optimal monetary policy responses may depend on movements in the current account.

Beginning with Hall (1978), rational expectations versions of the permanent income hypothesis have been tested frequently, using both aggregate and individual data. While they are capable of explaining broad movements in consumption and saving, tests of the hypothesis are usually statistically rejected. In light of this, it is not surprising that rational expectations versions of the intertemporal approach are typically statistically rejected as well. Nonetheless, we argue that the hypothesis captures some important features of current account dynamics that deserve inclusion in New Keynesian open-economy models.

Defining CA_t as the current account, A_t as net claims on foreign assets, Y_t as GDP, and I_t as investment, the savings-investment identity,

$$CA_t = r_t A_t + Y_t - C_t - I_t - G_t, \tag{21}$$

provides the relevant notion of income,

9. Of course, there were also richer general-equilibrium models of the intertemporal approach that included, for example, non-tradables or differing sets of tradables produced by different countries, thereby allowing the real exchange rate (measured as the relative price of non-tradables) or the terms of trade to affect the current account (Obstfeld 1982; Dornbusch 1983; Obstfeld and Rogoff 1996, chapter 4), but these did not receive as much empirical attention.

$$Q_t = Y_t - I_t - G_t. \tag{22}$$

This variable, which is termed "net income," represents the non-interest income available for private consumption after providing for investment and government demand of goods and services. Its role in the intertemporal approach is similar to the role of labour income in the life-cycle/permanent income hypotheses.

Combining equations (20)–(22) with the household's intertemporal budget constraint yields the implication that the current account should respond only to temporary deviations of net income:

$$CA_t = Q_t - Q_t^p, \tag{23}$$

where Q_t^p is the expected permanent level of net income. According to the equation, temporary shocks to output, investment, or government spending should affect the current account and permanent shocks should not, because consumers will attempt to smooth consumption in the face of temporary shocks by borrowing from or lending to the rest of the world, while permanent shocks cannot be smoothed away. Ahmed (1987) found some support for this hypothesis using historical data for the United Kingdom.

Following Campbell (1987), equation (20) can be rewritten in a form that implies that the current account should equal the expected present discounted value of all future declines in net income:

$$CA_t = E_t\left(\sum_{j=1}^{\infty} \frac{1}{(1+r)^j}\Delta Q_{t+j}\right). \tag{24}$$

Campbell's form of the equation emphasizes that the current account reflects expected future changes in the domestic output available to households. Thus, the current account should be in deficit if net income is expected to grow, while it should be in surplus if net income is expected to decline. Sheffrin and Woo (1990), Otto (1992), and Ghosh (1995) have tested this prediction for various countries. While the restrictions are formally rejected for most countries, the model's predictions often appear to work well in economic terms.

The equations above are only valid for a small open economy subject to idiosyncratic shocks. Simple extensions of the intertemporal approach to a global general equilibrium with larger countries or global shocks replace net income in these equations with relative net income:

$$RQ_t = Q_t - Q_t^w, \tag{25}$$

where Q_t^w is average world net income.[10] If all countries wish to borrow, then interest rates will rise but there will be little effect on capital flows because there is no counterparty willing to lend. Thus, if a shock is global, then general-equilibrium versions of the intertemporal approach predict that there should be little or no effect on the current account, while if a shock is country-specific, it should affect the current account. Glick and Rogoff (1995) have tested this implication of the theory. They find that the current account does in fact appear to respond more to country-specific productivity shocks than to global shocks.[11]

To what extent is this useful? Campbell's formula implies that the current account should be in deficit when households expect future relative net income to grow, and that it should be in surplus when relative net income is expected to decline. As seen in Table 1, on a rough level this matches the experiences of the United States, Germany, and Japan during the 1990s. The United States had a current account deficit of $111 billion measured in 1996 prices at the start of the decade, and its relative net income grew at a much faster rate than the historical average, while Germany and Japan both began with current account surpluses and experienced below average growth in relative net income during the decade.

To more formally test the ability of the intertemporal approach to fit the experience of the 1990s, we formed an estimate of the expected present value of future changes in relative net income for each quarter over the period 1960:1–2000:1 and compared this to the actual current account. We first estimated a two-equation system for each country, regressing relative net income and the current account on their lagged values using quarterly data up to 1989:4. At each time period, we then used these estimated equations to form a forecast of all future changes in relative net income based on the data available at that date. Using this forecast, we then calculated the implied expected present value of declines in relative net income. According to the theory, if our estimated equations are an accurate representation of household's expectations, this expected present value should equal the current account. The results are shown in Figure 1. In each case, the intertemporal approach is statistically rejected at the 1 per cent level. However, on an informal level, the theory does surprisingly well for the United States and Japan, though less well for Germany. In particular, the

10. In our empirical exercises, average "world" income is calculated using a GDP-weighted average of net income for the G-7 countries.

11. Glick and Rogoff find little response to either country-specific or global government spending shocks. They attribute this result to the difficulty of identifying temporary spending shocks.

Figure 1
Actual and implied current account

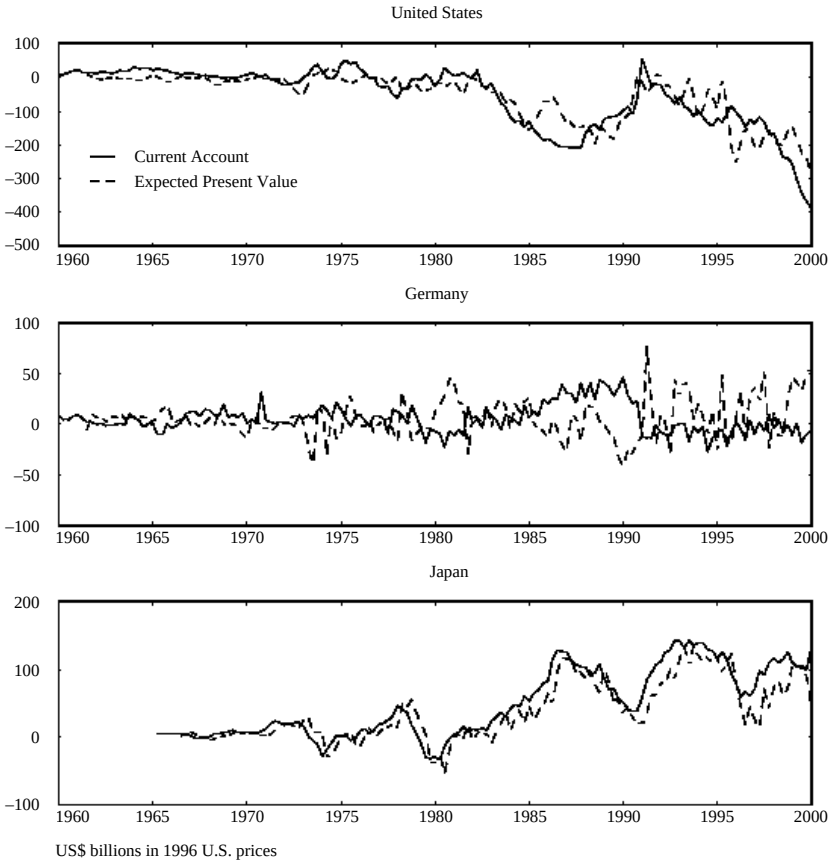

Table 1
The current account and future movements in relative net income

Country	Current account surplus	Average relative net income change
	1989:4	**1990–2000**
United States	–111.32	10.08
Germany	35.45	–9.01
Japan	55.92	–5.30

Notes: 1996 U.S. prices. Net income change compared to country average.

theory predicts that the German current account should have been more volatile than it was.

Overall, while it is statistically rejected, the intertemporal approach appears able to frequently match broad movements in the current account based on forecasted movements in relative net income, although it is not always able to match the exact magnitudes or timing of swings in these two variables. New open-economy models that allow for current account deficits in equilibrium hold the promise of enriching the intertemporal approach in several empirically relevant ways while also keeping some of its original insights into current account dynamics. Where the original approach did not allow for exchange rate effects on expenditure or for investment or intermediate good imports, as discussed in section 2.1.2, recent papers have begun to explore these issues in serious ways, although often in contexts in which current account dynamics are shut down. Several of these papers have begun to explore ways to allow for current account dynamics while maintaining a unique steady state that can be linearized around. Ghironi (2002), Cavallo and Ghironi (2002), and Smets and Wouters (2002) incorporate Blanchard-Yaari-type overlapping generations into their models. Benigno (2001a) and Kollmann (2001) instead maintain a unique steady state by assuming an exogenously specified risk premium that depends on net foreign asset positions. This line of work should eventually lead both to better models of the current account and to a better understanding of the extent to which monetary policy should depend upon the current account.

3 How Should Monetary Policy React to Exchange Rate Movements?

3.1 The implications of producer currency pricing

A number of papers have demonstrated environments featuring PCP in which the optimal monetary policy continues to target domestic variables even in an open-economy context. This work includes Galí and Monacelli (2002); Clarida, Galí, and Gertler (2001a); and Engel (2002), who all explicitly assume that international financial markets are complete, as well as Corsetti and Pesenti (2001b) and Sutherland (2000, 2002a), who assume a unitary elasticity of demand between domestic and foreign goods and separability of tradables consumption so that the equilibrium is identical to one in which financial markets are complete.

The economics of this result can be fairly easily demonstrated. To simplify notation, we follow what has become a standard parameterization of the utility function (6) by assuming that $\rho = \varepsilon = \upsilon = 1$. Under PCP, a profit-

maximizing domestic firm that must set its price one period in advance will set its price in domestic currency equal to the expected value of equation (4),

$$\bar{p}(z) = \left(\frac{\theta}{\theta - 1}\right) E_{t-1}(\kappa_t w_t). \tag{26}$$

Because firms are identical, all domestic firms set the same price and $P_h = \bar{p}(z)$. Likewise $P_f = e\bar{p}^*(z)$. Following Corsetti and Pesenti (2001a) in assuming that the consumption bundle is Cobb-Douglas as in equation (11), the domestic price index is

$$\begin{aligned} P &= P_h^{\gamma} P_f^{1-\gamma} \\ &= \left(\frac{\theta}{\theta - 1}\right)[E_{t-1}(\kappa_t w)]^t \left[E_{t-1}(\kappa_t^* w_t^*)\right]^{-\gamma}. \end{aligned} \tag{27}$$

Since the papers in question all effectively shut down movements in the current account, the result in question can be shown either in a static or dynamic setting without material effect. For simplicity we choose the static setting, which has the effect of simplifying equation (8) for money demand to

$$\frac{M_t}{P_t} = \chi^{\frac{1}{\varepsilon}} C_t^{\frac{\rho}{\varepsilon}}. \tag{28}$$

It is standard in this literature to evaluate welfare while ignoring the effects of real money balances on utility—that is, treating the parameter χ as if it were infinitesimal. Ignoring effects on real balances, there are two sources of economic distortion in this model: sticky prices and the markup charged by firms. Under the assumption that monetary policy cannot affect the distortions associated with firm's market power, the constrained Pareto optimum is to replicate the equilibrium under flexible prices. Comparing expected utility under sticky prices with expected utility under flexible prices is therefore the relevant loss function for the monetary authority,

$$\begin{aligned} L &= E_{t-1}(U) - E_{t-1}(U^{flex}) \\ &= E_{t-1}(\ln C) - E_{t-1}(\ln C^{flex}) \\ &= \gamma E_{t-1}\left(\ln \frac{\kappa_t w_t}{E_{t-1}(\kappa_t w_t)}\right) + (1-\gamma) E_{t-1}\left(\ln \frac{\kappa_t^* w_t^*}{E_{t-1}(\kappa_t^* w_t^*)}\right). \end{aligned} \tag{29}$$

The monetary authority wishes to minimize a weighted average of deviations of domestic and foreign producer currency prices from their flexible-price values. Under PCP, however, domestic monetary policy will only affect domestic producer currency prices—any movement it causes in the exchange rate will have no effect on foreign producer prices denominated in foreign currency because of the assumption of complete pass-through of exchange rate movements. Hence, the monetary authority should target domestic prices, P_h, and attempt to stabilize them at the flexible-price equilibrium level.[12] Under the assumed parameterization $w_t = M_t$, the best that the domestic monetary authority can do is to choose a monetary policy that sets marginal cost to a constant,

$$M_t = \frac{\text{constant}}{\kappa_t}.$$

This result is exactly what the monetary authority would attempt to do in a closed economy (where $\gamma = 1$) and, furthermore, if both monetary authorities adopt this policy then the fixed-price equilibrium will exactly replicate an equilibrium with flexible prices, leading to a constrained optimum. Tille (2002) points out that this result may not hold if there are sectoral shocks rather than country-specific shocks. Movements in the exchange rate change the relative price of goods across countries, but this will cause intrasectoral distortions if sectoral production occurs across countries.

The work of Obstfeld and Rogoff (2002) helps shed light on when the optimality of domestic stabilization should be expected to hold. Obstfeld and Rogoff introduce non-traded goods into the Cobb-Douglas formulation of the consumption index. If utility is separable between tradables and non-tradables (which occurs if $\rho = 1$ in this context) then, as discussed earlier, the equilibrium is identical to one in which markets are complete. If utility is non-separable $(\rho \neq 1)$, then the equilibrium will differ from the complete markets outcome, and this introduces another source of economic distortion into the economy. Because movements in the exchange rate can affect this distortion by shifting wealth between foreign and domestic consumers and thereby move the economy closer to an optimum, the monetary authority will no longer desire to target domestic prices alone. Obstfeld and Rogoff

12. This mirrors the result in Aoki (2001) who, in a closed economy setting, models two sectors, one with flexible prices and the other with sticky prices, and finds that optimal policy will target inflation in the sticky-price sector. Aoki informally argues that his result would imply targeting domestic prices in an open-economy setting with flexible exchange rates, as is confirmed in the latter papers we have cited. Benigno (2001b) looks at a single central bank setting policy for two countries, each with fixed- and flexible-price sectors.

conclude that the welfare benefits of altering monetary policy to take this effect into account are small in their model, but it is possible that it may be larger in other contexts.[13] It is important to note that the result is not affected by simply adding any source of distortion. Galí and Monacelli (2002) and Clarida, Galí, and Gertler (2001a) both assume that the price-setting is staggered based on the Calvo price-setting model. Staggering introduces another source of distortion by causing suboptimal variation in prices across firms. Clarida, Galí, and Gertler (2001a) further introduce frictions in wage-setting that may distort the real wage from its competitive level. However, because both types of distortion are purely domestic, neither alters the prescription that the monetary authority should target domestic variables under PCP pricing.

Obviously the assumption that real balance effects can be ignored plays a role in this result. If χ is non-negligible, then the monetary authority will also have to balance distortions to real money holdings caused by inflation. However, CPI inflation rather than domestic inflation alone affects money demand, and this implies that the monetary authority should target some weighted average of domestic and CPI inflation. Svensson (2000) emphasizes that monetary authorities may wish to explicitly include the exchange rate in their reaction function because exchange rate movements are likely to affect CPI inflation more quickly than domestic disturbances.

3.2 Incomplete pass-through

Several papers have begun to explore the extent to which incomplete pass-through affects the PCP prescription that monetary authorities should target domestic variables. This work includes Devereux and Engel (2000), Corsetti and Pesenti (2001b), Sutherland (2002a), Engel (2002), and Smets and Wouters (2002). These papers conclude that incomplete pass-through does in fact give the monetary authority an incentive to react to the exchange rate.

Following Corsetti and Pesenti, this result can be seen by generalizing the framework just presented to one in which import prices partially react to exchange rates:

13. Obstfeld and Rogoff's parameterization links the degree of risk aversion to the degree of non-separability between traded and non-traded goods. In theory, these may be distinct—for example, Corsetti and Dedola (2002) assume that non-traded distribution services must be combined with traded goods in fixed proportion in final consumption, so that the degree of non-separability is high while the degree of risk aversion is free to vary.

$$P_f = \left[\int_n^1 (e^{1-s}\bar{p}^*(z))^{1-\theta} dz\right]^{\frac{1}{1-\theta}}, \tag{30}$$

where $\bar{p}^*(z)$ is the fixed foreign currency price of imports. Note that $s = 0$ represents full pass-through (PCP) and $s = 1$ represents zero pass-through (LCP). As before, in equation (26), producers will set prices in their home market to equal a fixed markup over expected home marginal cost. In setting export prices, however, it will take into account the effect that exchange rate movements have on its revenue in terms of its home currency. With incomplete pass-though, firms will wish to set different prices in the two markets. Corsetti and Pesenti show that in equilibrium, foreign firms will set

$$\bar{p}^*(z) = \left(\frac{\theta}{\theta - 1}\right) E_{t-1}(e^s \kappa_t^* w_t^*). \tag{31}$$

As emphasized also by Bacchetta and van Wincoop (2000), Corsetti and Pesenti make the point that incomplete pass-through can raise export prices by causing foreign firms to charge a risk premium to compensate for exchange rate risk. If the exchange rate varies positively with foreign marginal costs, foreign firms will charge a higher price for their exports, reducing welfare for the domestic residents who import them. The domestic loss function in this case becomes

$$L = \gamma E_{t-1}\left\{\ln \frac{\kappa_t w_t}{E_{t-1}(\kappa_t w_t)}\right\} + (1-\gamma) E_{t-1}\left\{\ln \frac{e^s \kappa_t^* w_t^*}{E_{t-1}(e^s \kappa_t^* w_t^*)}\right\}. \tag{32}$$

Because the domestic monetary authority can affect the variability of the exchange rate and hence potentially lower the risk premium charged on domestic imports, it should no longer target the domestic price level only. Corsetti and Pesenti show that as s increases, the monetary authority will place an increasing weight on exchange rate stabilization. In a quite ambitious paper, Smets and Wouters (2002) fit a linearized version of this type of model of the euro area and conclude that under their estimated degree of pass-through, the welfare-optimizing monetary policy would target both domestic and import price inflation. In a similar framework, Sutherland (2002a) also concludes that the monetary authority will wish to include exchange rate movements in its target, but surprisingly finds that if labour supply is sufficiently inelastic, the monetary authority may wish to increase exchange rate variability rather than decrease it. The trade-off is that while exchange rate variability will cause a higher price for domestic imports, lowering the amount of imports in domestic consumption, it will

also decrease the amount of domestic goods sent for export, potentially leaving more for domestic consumption. If domestic labour supply is inelastic, this latter effect may predominate.

Devereux and Engel (2000) and Engel (2002) examine the case of full LCP and demonstrate that a co-operative fixed exchange rate regime can support the constrained optimum in their models. In the flexible-price equilibrium, the terms of trade will optimally fluctuate in response to country-specific shocks, allowing expenditure to shift towards goods that have lower marginal costs of production. Under full LCP, this expenditure-switching effect is completely shut down, because both domestically produced and imported goods prices are fixed in the short run and unresponsive to movements in the nominal exchange rate. The exchange rate will still affect capital flows, however. With complete risk-sharing (due either to a complete set of international financial markets or to a unitary elasticity of demand for domestic and imported goods and separability in traded consumption), domestic and foreign households will share risk by equating the marginal utility of one unit of home currency to domestic consumers with its marginal utility to foreign consumers in any state of nature:

$$\frac{1}{P}C^{-\rho} = \frac{1}{eP^*}(C^*)^{-\rho}. \tag{33}$$

At an optimum, domestic and foreign tradables consumption should be perfectly correlated. Under LCP, both P and P^* are fixed; hence, any movements in the exchange rate will drive a wedge between domestic and foreign tradables consumption and lead to a suboptimal outcome. Devereux and Engel show that the best that monetary authorities can do is to keep the exchange rate fixed. This policy will not replicate the flexible-price equilibrium, but will lead to the best outcome possible under LCP.

This result obviously makes great use of the assumption of complete risk-sharing. It is an open question if it must be significantly modified when risk-sharing is incomplete. Obstfeld and Rogoff (1995a) originally emphasized the permanent effects of monetary policy caused by shifts in wealth and the current account. In an incomplete market, setting the ability of monetary policy to effect cross-country shifts in wealth may be a welfare-improving tool.

4 Policy Coordination

Central banks are concerned not only with how to react to domestic and international shocks, but also with how other policy-makers around the world will react to these same shocks. Monetary policy in one country may

have policy spillovers on other countries. For example, if monetary policy has "beggar-thy-neighbour" expenditure-switching effects through the exchange rate, then a country's monetary policy actions, although beneficial from its own point of view, may have negative spillovers on other nations. In a Nash equilibrium, each nation maximizes only its own welfare subject to the reaction of other nations. Spillovers, whether they be negative or positive, give each nation the incentive to change the monetary policy instrument either "too much" or "not enough" as they try to gain at the expense of the others. In this Nash equilibrium, all countries are worse off than in a co-operative equilibrium in which they jointly maximize their welfare and internalize the cost or benefits of the spillovers.

The topic of international policy coordination is one on which many insightful papers have been written over the past several decades.[14] As of the late 1990s, there was reasonable consensus on several issues. First, there are potential gains from the coordination of fiscal or monetary policies as measured by the difference between a country's welfare function under the co-operative solution and under the Nash non-co-operative equilibrium, where each nation maximizes its own welfare. This result held both in the case of symmetric shocks (or global shocks, such as oil-price shocks) and perfectly asymmetric shocks. Second, empirical and calibrated estimates of the size of the gains to co-operation were deemed to be small, these being on the order of one-half of 1 per cent to 1 per cent of GDP per year.[15] Third, the size of gains may be small because of the relatively low degree of integration among economies. As goods and financial market integration rise, spillovers between nations may also rise, leading to larger empirical gains from co-operation.

Recent papers by Obstfeld and Rogoff (2002) and others have generated renewed interest in the analysis of policy coordination. They contain results derived using the new open-economy macroeconomic model outlined above. While there is still no consensus on the gains from co-operation, the use of a micro-founded open-economy model has yielded several important insights. Welfare analysis can make use of the micro-foundations of the model with policy-makers maximizing the utility of the households, rather than an ad hoc loss function. Policy spillovers are therefore explicitly spillovers onto utility, rather than macroeconomic variables. The use of

14. Useful surveys of the older literature include Canzoneri and Henderson (1991), Persson and Tabellini (1995), and McKibben (1997). For a recent survey that explores the relationship between the theory and actual practice of international policy coordination, see Meyer, Doyle, Gagnon, and Henderson (2002).

15. McKibben (1997) extensively reviews the literature on the estimation of policy coordination gains. Meyer et al. (2002) argue that the gains found in this literature are somewhat larger than the consensus view would suggest.

micro-founded models has highlighted how distortions in the economy, such as monopoly power and imperfections in capital markets along with nominal rigidities, create channels for spillovers between nations. The focus on these spillovers has raised new questions about the role that integration might play in the size of gains from co-operation. It has also underscored that different spillovers, under certain conditions, may give policy-makers incentives to change policy in opposite directions and diminish the overall externality that creates the opportunity for co-operative gains. The role these new distortions play has also been linked to the currency pricing decisions of firms, how different sectors are affected by shocks, and what the elasticity of substitution is between different goods. Finally, the newer literature departs from the old by looking at monetary policy rules—so policy-makers are choosing reaction-function parameters once rather than choosing responses each period.

The first of these papers, Obstfeld and Rogoff (2002), claims that there are no gains to coordination under certain assumptions, and quite limited gains under a broader set of plausible assumptions. Yet the primary contribution of Obstfeld and Rogoff to international policy coordination is not the result that the gains are small. This bottom line is the same basic result of many papers in the earlier literature. Furthermore, subsequent papers (discussed below) will call that result into question, and much more work will need to be done to achieve any sort of a consensus, if indeed that is possible. Rather, as discussed above, the paper highlights that the same new channels by which changes in the monetary policy rule can affect the economy can work against one another.

Obstfeld and Rogoff (2002) extend their earlier model (2000) to address the gains to coordination, setting $\nu = \varepsilon = 1$ in the expected utility version of equation (6). The authors rewrite the disutility-of-effort shocks so that they are similar to the symmetric and perfectly asymmetric shocks studied by the earlier coordination literature. Home, κ, and foreign, κ^*, disutility-of-effort shocks are used to create:

$$\kappa_w = \frac{1}{2}(\ln\kappa + \ln\kappa^*) \qquad \kappa_d = \frac{1}{2}(\ln\kappa - \ln\kappa^*), \tag{34}$$

where κ_w is a symmetric (or world) disutility-of-effort shock, and κ_d is a perfectly asymmetric (or "difference") disutility-of-effort shock.

Policy-makers in this model face three kinds of relevant distortions.[16] The first, of course, is sticky wages, the same distortion as in the older literature

16. The model also includes a terms-of-trade distortion, where either country could raise its own welfare by imposing an import tariff. See Obstfeld and Rogoff (2002) for a further explanation of why this distortion does not play a role here.

that enables monetary policy to have an effect on real variables in the economy in the short run. The second distortion is the monopoly power of workers that enables them to set wages higher than and to work less than the competitive level. Even when monetary policy is set according to a rule, ex ante a central bank can affect the level of nominal wages by affecting the level of risk facing workers. The third distortion is that markets may be incomplete, so that consumers in home and foreign countries can only imperfectly share risks, such as when households can trade only real bonds. Pre-commitment to a coordinated policy rule could help share risks across countries. For example, if the home country is faced with only a positive asymmetric disutility-of-effort shock (and foreign a negative one), $\kappa_d > 0$, $\kappa_w = 0$, then both home and foreign monetary policy can cause an appreciation of home's exchange rate, helping home purchase more of foreign's exports for fewer of home's exports.

To solve for the welfare gains to coordination, Obstfeld and Rogoff solve the model for home and foreign household utility in the limiting case when the utility gained from liquidity services goes to zero, $\chi \to 0$:

$$E(U) = \left(\frac{1}{1-\rho} - \frac{(\phi-1)(\theta-1)}{\varphi\theta}\right)$$

$$\exp(1-\rho)E(x) + \frac{(1-\rho)(1-\gamma)}{2}E(\tau) + \frac{1-\rho}{2}\sigma_x^{\,2} + \frac{(1-\rho)(1-\gamma)^2}{8}\sigma_\varepsilon^{\,2} + \frac{(1-\rho)(1-\gamma)}{2}\sigma_{xe} \quad (35)$$

$$E(U^*) = E(U) - (1-\gamma)E(\tau), \quad (36)$$

where $E(x)$ is the expected value of world tradables spending, and $E(\tau)$ is the expected terms of trade. One can start to see the possibility for spillovers by noticing that the expected terms of trade enters in home and foreign's utility functions with opposite signs. These potential spillovers may affect both the average levels as well as the variances of variables. For example, the expected terms of trade, $E(\tau)$, is lowered by an increase in the covariance of nominal exchange rates with the world disutility-of-effort shock, $\sigma_{\kappa_w e}$. A higher $\sigma_{\kappa_w e}$ will mean that home wages, set one period ahead of time, will be higher relative to foreign, since home's relative marginal utility of consumption will be low when home labour supplies and world marginal disutility of effort are high.

Before any other agents act, the monetary authority commits to a monetary policy rule where the money stock of each nation is a function of the disutility-of-effort shocks:

$$\hat{m} = -\delta_d\hat{\kappa}_d - \delta_w\hat{\kappa}_w, \quad (37)$$

where m is the logarithm of the money stock and, in contrast to section 2.1.2, carats or hats (^) over variables now denote surprise components, e.g., $\hat{\kappa}_d = \kappa_d - E\{\kappa_d\}$. So, in the Nash solution, for example, the home country maximizes expected utility by choosing δ_d and δ_w, subject to its own monetary policy rule and the reaction coefficients of the foreign country. In the co-operative case, the countries jointly maximize a weighted average of their utilities,

$$E(V) = \frac{1}{2}(E(U) + E(U^*)), \tag{38}$$

by choosing δ_d, δ_w, δ_d^*, and δ_w^*, again subject to the form of their monetary policy rules.

Even though households cannot trade contingent securities, when households derive utility from the logarithm of consumption and there is a unitary elasticity of substitution between home and foreign tradable goods, tradables consumption at home and abroad will be equal in all states of nature. In other words, although there is no trade in contingent securities in this model, the economy will behave similarly to the case where markets are complete and our third distortion disappears. In this case, where $\rho = 1$, both home and foreign monetary policy are the same in the co-operative solution as they are in the Nash equilibrium. The result comes about because the utility effects of the two remaining distortions, those due to sticky wages and monopoly power, are separable and cannot be affected by a commitment monetary policy.[17] When $\rho = 1$, home's utility function (equation (35)) reduces to

$$E(U) = E(x) + \left(\frac{1-\gamma}{2}\right)E(\tau) - \text{constant}. \tag{39}$$

Expected utility under co-operation (equation (38)) reduces to

$$E(V) = E(x) + \text{constant}. \tag{40}$$

In both cases, nations care about the expected world value of spending on tradables, x. Even though the terms of trade enters into the two non-co-operative utility functions in opposite directions, the logarithmic form of consumption and unitary elasticity of substitution between home and foreign tradables has strong implications for each nation's behaviour. As outlined above, these assumptions also ensure that the current account remains in balance. In reaction to a perfectly asymmetric increase in the

17. Corsetti and Dedola (2002) show that when markets are competitive, the Obstfeld and Rogoff result still holds.

marginal disutility of effort only, $\kappa_d > 0$, $\kappa_w = 0$, the home central bank will decrease the money supply (and foreign will loosen), appreciating the home currency. Home workers will want to work less, so the home policy-maker's tightening will shift work away from home towards foreign, while at the same time increasing home's purchasing power, keeping consumption and the utility of work effort at the same level that would prevail in the absence of the shock. The important point is, as Obstfeld and Rogoff show, this non-co-operative outcome will replicate the equilibrium when prices are flexible for both countries and hence each nation has no incentive to deviate from it. In other words, under these conditions there are no policy spillovers.

In the case where $\rho \neq 1$, the economy no longer mimics the case of complete markets, and the marginal utility of tradables consumption depends on the consumption of non-tradables. When $\rho > 1$, as is more plausible, non-co-operative policy-makers will react less than is optimal when faced with an asymmetric increase in the marginal disutility of effort. When home commits to tighten the money supply in response to positive κ_d shocks, non-tradable production will suffer as well as tradable. Since the marginal utility of tradables consumption depends positively on non-tradable consumption, home will not want to contract as much as it did when the utilities of consumption were separable. Both countries could gain by co-operating and reacting more to the shock, since it would shift more production from the home to the foreign country. There will be gains to co-operation as each country can at least partially insure the other against asymmetric disutility-of-effort shocks. In the face of a perfectly asymmetric increase in home's disutility of effort, foreign can loosen and home tighten its money supply more than is nationally optimal, and consequently increase welfare in both countries.

Obstfeld and Rogoff conduct simulations of the model to demonstrate that the gains when $\rho \neq 1$ are relatively small—thousandths of a per cent of output—and are dwarfed by the gains to stabilization, except at an implausibly high level of risk aversion, $\rho > 100$. Furthermore, the gain from coordination relative to the gain from stabilization decreases as ρ gets closer to 1 from above. Since the gains are zero only at $\rho = 1$, when the model replicates the complete markets outcome for consumption, Obstfeld and Rogoff conclude that the gains to coordination become smaller as economies become more integrated.

Also, in contrast to the earlier literature, Obstfeld and Rogoff show in their model that there are no gains to co-operation when there are only global disutility-of-effort shocks, $\kappa_d = 0$, $\kappa_w > 0$, even when $\rho \neq 1$. Under a global shock to both sectors, without co-operation the monetary authority can still replicate the equilibrium when prices are flexible, because of the

separability of the monopoly and sticky-wage distortions. When $\rho \neq 1$, since the two countries are symmetric, any risk-sharing is precluded because a global shock affects them equally.

Subsequent papers have shown that three of these results may depend on particular assumptions. First, as Corsetti and Pesenti (2001b) show, interestingly enough, with only partial indexation of prices to exchange rates, there will be gains to international co-operation. The authors introduce a term into an extension of an earlier version of their own model that measures the degree of pass-through. With complete pass-through, they can demonstrate the Obstfeld and Rogoff result that there are no gains to co-operation in response to an asymmetric shock in the disutility of effort when $\rho = 1$. With no pass-through, Corsetti and Pesenti also conclude that there are no gains, because now there are no policy spillovers. They do not assess the size of the gains in the intermediate case.

Second, Canzoneri, Cumby, and Diba (2002) show that if there is no longer a uniform effect of the shock across sectors, there are gains to coordination when economies are hit by a common shock. While such a shock is no longer strictly a global shock in the same sense as in the earlier literature, this fact in no way diminishes its importance. Canzoneri, Cumby, and Diba motivate differences in the sectoral responses by appealing to the possibility of differences in productivity across sectors. For example, the literature on the Balassa-Samuelson effect suggests that there are productivity differences across traded and non-traded sectors. The authors also appeal to differences in the degree or type of nominal rigidities across sectors. In light of work by Erceg, Henderson, and Levin (2000), they suggest that decentralizing production and introducing an asymmetry in price stickiness across sectors can lead to a policy trade-off even when shocks are global. The authors look at three additional extreme cases, each of which gives increasingly larger gains: (i) when there are only shocks to the tradable goods sector and none to the non-tradable goods sector; (ii) when there are only shocks to the non-tradable goods sector and none to the tradable sector; and (iii) when there are only shocks to the export sector. Under their parameterization, the authors claim that the first case yields gains to coordination that are on the same order as those found in the earlier literature, while the other two cases yield gains that are larger and more significant.[18]

18. Clarida, Galí, and Gertler (2001b) also show that there are gains to coordination in the face of cost-push shocks.

Finally, according to Sutherland (2002b),[19] changing the model so that agents are allowed to trade contingent contracts after the central banks choose their monetary policy rule challenges the Obstfeld and Rogoff claim that increasing financial integration actually decreases the gains from coordination. Sutherland shows that another important assumption to relax is that of a unitary elasticity of substitution between home and foreign tradable goods.[20] Instead, Sutherland assumes tradable consumption follows equation (9), where $\gamma = 1/2$ and where $\varphi \geq 1$. When the utility of consumption is logarithmic, $\rho = 1$, and the elasticity of substitution between home and foreign tradables is greater than one, $\varphi > 1$, Sutherland shows that there are tiny gains to co-operation when agents cannot share risk. When they can share risk, however, there are larger, but still small (tenths of a per cent of steady-state consumption) gains. These gains are even larger when $\rho > 1$, and we move from financial autarky to risk-sharing, with absolute gains rising to around 1 per cent of steady-state consumption with risk-sharing. While larger in absolute terms, these gains are comparable to those estimated by the earlier literature. Nonetheless, the relative gains of co-operation under risk-sharing compared with the gains to stabilization are substantial. The reasons for these gains are twofold. First, with the ability to trade a full set of contingent contracts, home and foreign consumption are now equal in every state. Second, with $\varphi > 1$, the potency of the expenditure-switching effects of monetary policy is increased. An increase in home's marginal disutility of effort will give home an incentive to shift output from home to foreign, with a smaller consequence for its own consumption than under financial autarky. Changing φ, financial integration, or ρ individually, has only small effects, but changing all three produces larger gains. These possible gains increase as households become more risk-averse.[21]

This more recent literature in policy coordination is still composed of relatively few papers and as such has not picked up a host of issues that the earlier and more extensive literature tried to address. These new papers focus primarily on the gains from co-operation when the central bank can commit to a monetary policy rule (such as equation (37)) both in the Nash and the co-operative equilibria. Because of these rules, it is not important to

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19. Sutherland (2002b) also explores the possibility of allowing agents to sign contingent contracts before monetary policy-makers set their rules. Under this second form of risk-sharing, the potential gains to international policy coordination are even larger. Devereux (2001) and Benigno (2001a) also look at the role of financial market structure in policy coordination.

20. Benigno and Benigno (2001) also look at this important case.

21. Sutherland arrives at his solutions by using a second-order approximation of the welfare function. He outlines the technique in Sutherland (2002b).

look at any more than a one-shot game, and the co-operative equilibrium is assumed to be enforceable. The earlier literature, in contrast, looked at equilibria where central banks still had discretion, and thus, also explored ways in which co-operation might be supported, such as by reputational equilibria in repeated games.[22] Other earlier work explored the role of information, for example, looking at the role that model uncertainty and information exchange played in calculating the gains to policy coordination.[23] A few earlier papers sought larger gains to coordination by comparing equilibria other than the co-operative and conventional non-co-operative outcomes. For example, Canzoneri and Edison (1990) find larger gains to coordination by comparing a non-co-operative outcome where the two countries have correct information about the size of economic variables to a non-co-operative equilibrium where the countries are making decisions based on a estimate. One of the challenges of the new literature is to use the advantages of the more micro-founded framework to address some of these issues while not becoming weighed down by the difficulties of the model.

Even when there are gains to co-operation, it is not clear that international policy coordination must involve countries making explicit agreements. In the earlier literature, authors argued that since countries will repeatedly face situations where there are gains to co-operation, then even when they have discretion, the possibility or threat of lower welfare in the future will help to support co-operation today. The recent literature assumes that central banks decide on policy rules that will hold for the foreseeable future. It is not unreasonable to believe that rational central banks that are committing to actions into the future will choose policy rules that will enact the co-operative solution and improve their welfare. Furthermore, there is a belief by some that central banks may not in practice face a time-consistency problem over domestic inflation expectations—either because of the belief that central bankers do not have output-gap targets that are "too high" or because central bankers understanding the problem can resist temptation. Modelling central bank behaviour as a policy rule assumes away this time-consistency problem. It may also not be unreasonable to believe that policy-makers may have an incentive to enact something approximating globally optimal policy without the need for explicit agreements.

22. See Canzoneri and Henderson (1991).
23. See Ghosh and Masson (1994).

Conclusions

In his 1993 Graham lecture, Paul Krugman laid out four challenges that represented not only important problems facing open-economy macroeconomics, but constraints on our ability to give useful advice to policy-makers. First, he felt we needed an open-economy macroeconomic model with nominal rigidities that we could integrate with modern trade theory. Second, we required a sticky-price open-economy macroeconomic model that also took an intertemporal approach to the current account. Third, we needed to incorporate into our macroeconomic models expectations that "made sense," particularly to help explain the behaviour of asset markets. Finally, we needed a better understanding of the microeconomics of using a common currency.

Almost a decade later, while we have not solved all of the field's great mysteries, open-economy macroeconomics has made at least some progress in each of these areas, and holds great promise in understanding more. We now have general-equilibrium multi-country models with nominal rigidities that have monopolistically competitive firms and international trade. We have models with intertemporal utility-maximizing agents that also have sticky wages or prices. We have stochastic models where there is a link between variances and covariances and the levels of macroeconomic variables, including the exchange rate. And we have models where the economy's response to monetary policy and monetary policy-makers' optimal reaction to movements in the exchange rate depend on such things as the preferences of households and the degree of pricing to market. All of these advances have increased our understanding of the effects of monetary policy.

This body of work lays out an important framework for answering normative questions such as what variables monetary policy authorities should react to in an open economy, and whether there are gains to central banks co-operating. Many unanswered questions remain, however. The results of the existing literature depend very much on the functional form and parameter values of the models' elements and often involve assumptions that shut down current account dynamics. While there have been several excellent papers that try to estimate or calibrate more realistic forms of these models, such as Bergin (2003) and Ghironi (2000), further work in this area is needed. We hope that not only will these models continue to yield a better understanding of the open macroeconomy, but that they will also lead to new empirical insights by helping to show us where to look.

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