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EXCHANGE RATE PASS-THROUGH AND THE WELFARE EFFECTS OF THE EURO*

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This article explores the implications of the European single currency within a simple sticky price intertemporal model. We focus on the question of how the euro may change the sensitivity of consumer prices in Europe to exchange-rate changes. Our central conjecture is that the acceptance of the euro will lead European prices to become more insulated from exchange-rate volatility. We find that this affects both the volatility and *levels* of macroeconomic aggregates in both the U.S. and Europe. We find that European welfare is enhanced, and the U.S. shares in Europe's good fortune.

1. INTRODUCTION

The implementation of the single currency in Europe has received a great deal of attention from the public, the press, and the academic literature. Much of the academic literature has discussed the question of whether Europe is an "optimal currency area," in the sense of Mundell (1961) and McKinnon (1963). This literature has assumed that the main effect of the adoption of the euro is to fix permanently the currency exchange rates in Europe. Much of the debate has revolved around the importance of asymmetric country shocks in the European business cycle.[2]

Another strand of the academic literature shares the popular view that the adoption of the euro is a more fundamental change. For instance, the role of the euro as an international currency has been explored by Hartmann (1996) and Portes and Rey (1998). While at present world trade and financial flows are carried out predominantly in U.S. dollars, the relative importance of the dollar may diminish as the euro becomes more widely acceptable in international transactions. The euro may become a "vehicle currency" that competes with the U.S. dollar, just

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[2] See, for instance, Eichengreen (1992), Bayoumi and Eichengreen (1993), De Grauwe (1994), and Obstfeld and Peri (1998).

as the U.S. dollar in a previous epoch competed with (and eventually replaced) the use of sterling.

We focus on one aspect of the adoption of the euro as an international currency that has heretofore been neglected, but which has potentially significant effects for macroeconomic stability. When Europe becomes integrated into a single large currency area, approximately equal in size to the U.S., it is likely that euro consumer prices will become as insulated in the short run from exchange-rate changes, as indeed U.S. prices have been since the dollar became the major vehicle currency. It is easy to understand this shift from a transactions-cost perspective. Take the situation of a U.S. firm that sells goods in Europe. When there are a dozen European currencies within the EMU, the firm faces two types of costs when exchange rates fluctuate. On the one hand, there are menu costs from altering the price that consumers pay, as the exchange rate changes. This encourages the firm to keep prices stable in consumers' currencies.[3] But if prices are set in the consumers' currencies, the firm's profits will be exposed to exchange-rate volatility. With a dozen European currencies, the U.S. firm would need a dozen pricing decisions, and a dozen exchange-rate hedging operations. These transactions costs would tend to tilt firms toward stabilizing prices in dollar terms, which would mean that the prices consumers pay would be more sensitive to changes in the dollar exchange rate.

When Europe is consolidated into a single-currency area, the accounting costs for pricing in the European consumers' currency may be reduced considerably. For example, it is more likely that U.S. exports will be invoiced in euros.[4] But even if U.S. export price invoicing does not change, multinational marketers are more likely to view Europe as a single marketing area and will develop pricing plans in terms of euros.[5] The importance of the euro as a payment and invoicing currency has recently been recognized by the European Central Bank:

> . . .increasing use of the euro as a payment/vehicle and pricing/quotation currency. . . could make the euro area Harmonized Index of Consumer Prices (HICP) less sensitive, in the short run, to U.S. dollar exchange rate movements. . . . If euro area exports and imports are increasingly invoiced in euro, the short-term effects of exchange rate changes on the goods and services trade balance should be generally reduced.[6]

We explore this issue within an international macro model with sticky nominal prices, so that the currency of denomination for the prices of imported consumer goods has real effects on macroeconomic aggregates and welfare. Our central conjecture is that the introduction of the euro will insulate European consumer prices from exchange rate changes. As a consequence, the introduction of the euro will affect the volatility of real money balances, and in turn macro aggregates

[3] In addition, firms selling their goods in several markets may find it optimal to price discriminate across markets as it provides them with an additional degree of freedom (see Friberg, 2000).

[4] Currently, there is an asymmetry such that U.S. exports to Europe are heavily invoiced in dollars, but European exports to the U.S. are also invoiced in dollars. See ECU Institute (1995). Giovannini (1988) observes that the currency of export price invoicing is important for the pass-through of exchange rate changes to goods prices.

[5] Much as IKEA sets dollar prices for the entire U.S. market (see Haskel and Wolf, 1999).

[6] European Central Bank (1999).

such as consumption, in Europe. With high pass-through from exchange rates to prices, the full effects of a monetary shock in Europe will be dissipated by a nominal exchange rate depreciation; European real money balances rise by less than nominal money balances. On the other hand, a U.S. monetary shock will tend to quickly pass-through to European real money balances through the channel of nominal depreciation.

If European and U.S. monetary shocks are about equal in size, and less than perfectly correlated, the introduction of the euro will increase real monetary instability in Europe. Intuitively, pre-euro there is a sort of diversification effect when European prices respond quickly to the exchange rate. The variance of a weighted sum of European and U.S. money shocks determines European real money volatility. Some of the European monetary variance is dissipated through exchange-rate changes, whereas the exchange rate transmits some of the U.S. monetary variance. But when the exchange-rate effect on European prices diminishes, the diversification effect dwindles. In the extreme case of no short-run price response to exchange-rate changes, European real money variance is determined by the variance of European money shocks (which is greater than the variance of a weighted sum of European and U.S. shocks). If this constituted the entire effect of the euro, then European consumers would be worse off (and U.S. consumers would be unaffected).

But there is a second channel through which the euro affects welfare. Our model follows Obstfeld and Rogoff (1998) in that goods prices are set optimally, taking into account the stochastic environment that is faced by the firms. This implies that the introduction of the euro will alter not just the volatility of macroeconomic aggregates, but through the adjustment of goods prices, change the *expected values* of these aggregates (see Devereux and Engel, 1998). We find that the introduction of the euro increases expected aggregate consumption in Europe, through a relative-price stabilizing effect. As Rogoff (1996) has noted "short-term exchange volatility points to financial factors such as changes in portfolio preferences, short-term asset price bubbles, and monetary shocks. Such shocks can have substantial effects on the real economy in the presence of sticky nominal wages and prices." In particular, before the advent of the euro, the model says that prices paid by consumers for imported goods are excessively volatile. They respond to exchange rate changes which, in the short run, do not reflect real demand and supply factors, but rather react as asset prices to financial market shocks. We find that when prices are stabilized in euros and unresponsive in the short run to exchange rate fluctuations, the elimination of the volatility of relative prices of imported to domestically produced goods enhances expected consumption and welfare.

Since our model is utility based, we can ask how the euro affects expected utility of U.S. and European consumers.[7] We find that for Europeans the positive effects from the reduction in relative-price volatility outweigh the increase in real monetary volatility. Some simple numerical calibrations indicate that the gains to Europe from the introduction of the euro are substantial when compared,

[7] Of course, we do not contend that this represents the full welfare effect of the euro, since we are ignoring many other impacts that have been highlighted in the literature.

for example, to the gains that might accrue from the elimination all monetary variability.

A common view of the coming of the euro is that whereas Europe will gain, the United States must be a loser.[8] On the contrary, we find that the U.S. shares in Europe's good fortune. The channels that reduce relative-price volatility and insulate Europe from U.S. monetary shocks are reflected in increased asset prices. To the extent that Americans are diversified internationally—our model assumes full diversification for simplicity—their portfolio of assets will also increase in value.

The article is organized as follows. The next section develops the basic model. Section 3 derives our central positive results, the welfare impact being discussed in Section 4. A numerical example is presented in Section 5. Section 6 contains a discussion of the empirical support for the central assumptions of the model. Section 7 concludes. Our set-up is similar to Devereux and Engel (1998), and we focus on the main steps of the analysis for brevity. An appendix detailing the solution of the model is available from the authors upon request.[9]

2. THE MODEL

We consider a general equilibrium model in which the world is made of two regions, which we refer to as the United States and Europe. Each region is populated by a continuum of households. We normalize the world population to 1, and assume that households over the $[0, n)$ interval are residents of the United States, whereas households over the $[n, 1]$ interval live in Europe. There also exists a continuum of firms in both regions, with the measure of firms in each region equal to the measure of households. Within each region, firms are owned by the domestic households. Our framework is characterized by monopolistic competition. Each firm enjoys a degree of monopoly power in pricing as it is the sole producer of a particular brand, which is an imperfect substitute for the other available brands.

Throughout the analysis, there is only one currency used in the United States, namely the U.S. dollar. By contrast, there are initially several currencies in use in Europe, which are replaced by a unique currency, the euro. To simplify the exposition, we consider Europe as one region, and present our results in terms of Europe-wide per capita values. We could, instead, write the model by considering a number N of European countries. Note, however, that once the euro has been introduced, all European countries have the same currency and are identical. We assume that pre-euro European countries follow a fixed exchange-rate regime. This implies that the economic situation is the same in all European countries,[10] and nothing is lost by focusing on Europe-wide aggregates.

In each country, there is a monetary authority, and the money supply fluctuates stochastically.[11] Before the introduction of the euro, each European country has its

[8] For example, Portes and Rey (1998) and Bergsten (1999).

[9] The appendix can also be found in Devereux et al. (1999).

[10] Our analysis does not consider the case of asymmetric shocks across European countries. In such a case, the economic situation would not be homogeneous within Europe.

[11] In our setup such fluctuations are equivalent to velocity shocks.

own monetary authority, whose behavior may be constrained by the requirements of fixed intra-European exchange rate. With the setup of the single currency area, European money supply is taken over by the European Central Bank.

2.1. *Households*

2.1.1. *Preferences.* Households obtain utility from consumption and the liquidity services provided by holdings of real balances, but incur disutility from working. The objective of household x, living in region i at time t is to maximize her intertemporal utility given by

$$(1) \qquad U_{it}(x) = E_t\left\{\sum_{s=t}^{\infty}\beta^{s-t}\left[\frac{1}{1-\rho}\left(C_{is}(x)\right)^{1-\rho} - \eta L_{is}(x) + \chi \ln\left(\frac{M_{is}(x)}{P_{is}^{i}}\right)\right]\right\}$$

where $\beta \in (0,1)$ is the discount factor, ρ is the intertemporal elasticity of substitution, which we assume to be greater than 1 as this is the empirically relevant range. η and χ are positive scaling parameters. $C_i(x)$ is a consumption basket defined below, $L_i(x)$ is the number of hours worked, $M_i(x)$ denotes the holdings of domestic currency, and P_i^k is the price of one unit of the basket consumed in region i, expressed in terms of region k currency ($k = eur$ denotes a price in the European currency, whereas $k = dol$ denotes a price in U.S. dollars). This is a quite a special utility function, with a linear cost of effort. But it has the appeal that it allows us to derived *closed form* solutions for consumption and welfare in the face of uncertainty in money supply and differences in pricing arrangements across countries.

The consumption basket $C_i(x)$ is a composite of goods produced in the United States and those produced in Europe:

$$C_i(x) = \frac{1}{n^n(1-n)^{1-n}}\left(C_{i1}(x)\right)^n\left(C_{i2}(x)\right)^{1-n}$$

where $C_{ij}(x)$ is the consumption by household x, living in region i, of the goods produced in region j. We denote the United States as region 1 and Europe as region 2. The elasticity of substitution between goods from different regions is equal to unity. Each region-specific basket $C_{ij}(x)$ is in turn a basket across the different brands produced in that region,

$$C_{i1}(x) = \left[n^{-1/\lambda}\int_0^n \left(C_{i1}(x,v)\right)^{\lambda-1/\lambda}dv\right]^{\lambda/\lambda-1}$$

$$C_{i2}(x) = \left[(1-n)^{-1/\lambda}\int_n^1 \left(C_{i2}(x,v)\right)^{\lambda-1/\lambda}dv\right]^{\lambda/\lambda-1}$$

where $C_{ij}(x, v)$ is the consumption by household x, living in region i, of the brand produced by firm v in region j. The elasticity of substitution between brands produced within a region is λ, which we assume to be greater than 1.

2.1.2. *Consumption allocation.* The optimal allocation of a given overall consumption basket $C_i(x)$ across the various available brands is given by

$$(2)\qquad \begin{aligned} C_{i1}(x, v) &= \frac{1}{n}\left[\frac{P_{i1}^i(v)}{P_{i1}^i}\right]^{-\lambda} C_{i1}(x) = \left[\frac{P_{i1}^i(v)}{P_{i1}^i}\right]^{-\lambda} \frac{P_i^i C_i(x)}{P_{i1}^i} \\ C_{i2}(x, v) &= \frac{1}{1-n}\left[\frac{P_{i2}^i(v)}{P_{i2}^i}\right]^{-\lambda} C_{i2}(x) = \left[\frac{P_{i2}^i(v)}{P_{i2}^i}\right]^{-\lambda} \frac{P_i^i C_i(x)}{P_{i2}^i} \end{aligned}$$

where $P_{ij}^k(v)$ is the price, expressed in region k currency, charged in region i for brand v produced in region j. P_{ij}^k is the price index, expressed in region k currency, charged in region i for goods produced in region j. The price indexes are written as

$$(3)\qquad \begin{aligned} P_{i1}^k &= \left[\frac{1}{n}\int_0^n P_{i1}^k(v)^{1-\lambda}\,dv\right]^{1/1-\lambda} \qquad P_{i2}^k = \left[\frac{1}{1-n}\int_n^1 P_{i2}^k(v)^{1-\lambda}\,dv\right]^{1/1-\lambda} \\ P_i^k &= \left(P_{i1}^k\right)^n \left(P_{i2}^k\right)^{1-n} \end{aligned}$$

2.1.3. *Optimal intertemporal choice.* We now turn to the conditions describing the optimal intertemporal choice of households. We assume that there are complete asset markets, so that the residents of each country can purchase state-contingent nominal bonds.[12] As all households are identical within each region, we can drop the x index and interpret the variables as per capita variables. The optimal risk-sharing condition between regions can be derived as

$$(4)\qquad \frac{S_{12t}\,P_{2t}^{eur}}{P_{1t}^{dol}} = \left(\frac{C_{1t}}{C_{2t}}\right)^{\rho}$$

where S_{12} is the exchange rate between the U.S. dollar and the European currency (the number of U.S. dollar per unit of European currency), the latter being a basket of European currencies before the introduction of the euro, and the euro itself thereafter. Equation (4) shows that consumption will differ across the two regions

[12] As Obstfeld and Rogoff (1998) emphasize, the structure of the utility functions ensures that consumption risk is completely shared when the law of one price holds. But in general, as we see below, the law of one price will not hold. In the absence of complete markets, this would imply a time-varying distribution of wealth among countries, and movements in the current account. To incorporate endogenous wealth distribution with incomplete markets would enormously complicate the analysis of the world equilibrium, probably without giving a lot of further insight into the issues addressed here. The redistributive effect of financial markets without risk sharing is likely to a relatively minor factor, from a welfare perspective. It is for this reason that as a first pass at this problem, one is justified in ignoring market incompleteness.

only to the extent that there are changes in the real exchange rate. Intuitively, optimal risk sharing implies that an additional unit of any currency has the same marginal utility regardless of the nationality of the household receiving it. We can compute the money demand as

$$\frac{M_{it}}{P^i_{it}} = \frac{\chi C^{\rho}_{it}}{(1 - E_t d_{it+1})} \tag{5}$$

where $E_t d_{it+1}$ is the inverse of the gross nominal interest rate, and d_{it+1} given by $d_{it+1} = \beta[C^{-\rho}_{it+1} P^i_{it}][C^{-\rho}_{it} P^i_{it+1}]^{-1}$.

Labor markets are competitive. Nominal wages are flexible (i.e., not preset). Denoting the nominal wage by W_{it}, the labor supply reflects the trade-off between consumption and leisure and is written as

$$W_{it} = \eta P^i_{it} C^{\rho}_{it} \tag{6}$$

The role of government is limited to issuing money and paying the seignorage revenue to the households in the form of a lump sum transfer.

2.2. *Firms*

2.2.1. *Output demand.* The demand faced by a firm producing a brand v is obtained by aggregating the consumption demands (2) across all households worldwide. The demand faced by a U.S. and European firm is then given by

$$\begin{aligned} Y_1(v) &= n\left[\frac{P^{dol}_{11}(v)}{P^{dol}_{11}}\right]^{-\lambda} \frac{P^{dol}_1 C_1}{P^{dol}_{11}} + (1-n)\left[\frac{P^{eur}_{21}(v)}{P^{eur}_{21}}\right]^{-\lambda} \frac{P^{eur}_2 C_2}{P^{eur}_{21}} \\ Y_2(v) &= n\left[\frac{P^{dol}_{12}(v)}{P^{dol}_{12}}\right]^{-\lambda} \frac{P^{dol}_1 C_1}{P^{dol}_{12}} + (1-n)\left[\frac{P^{eur}_{22}(v)}{P^{eur}_{22}}\right]^{-\lambda} \frac{P^{eur}_2 C_2}{P^{eur}_{22}} \end{aligned} \tag{7}$$

where $Y_i(v)$ is the total output of the firm producing brand v and located in country i. We assume that firms use a linear production function through which one hour of labor yields one unit of output.

2.2.2. *Price setting.* Prices must be set prior to the realization of shocks. Firms can set prices either in the consumers' currency, in which case they bear the exchange rate risk, or in the currency used by the firm, in which case the exchange rate risk is passed through to the consumers.[13] Because of the complexities of dealing with multiple menu costs, we do not attempt to directly model the optimal choice of currency of price setting. The intuition developed in the introduction, and the excerpt from the European Central Bank bulletin strongly suggests, however,

[13] Such a distinction is, of course, irrelevant for domestic sales, as the consumers and the firm use the same currency.

TABLE 1
CURRENCY OF PRICING

Region of Production	Region of Consumption	Currency	Pass-Through to Consumer
Before the euro			
United States	Europe	US dollar	*Complete*
Europe	United States	US dollar	Zero
After the euro			
United States	Europe	euro	*Zero*
Europe	United States	US dollar	Zero

that the euro will lead U.S. firms selling in Europe to stabilize their prices in euros. Therefore, we investigate the impact of the euro in the post-adjustment phase, in which a substantial degree of pricing of U.S.-manufactured goods in Europe has switched from dollar-denomination to euro-denomination. More specifically, pre-euro, the U.S. firms sets the price of goods sold in Europe in dollars, but once the euro is introduced, prices are set in euros. Therefore, the effect of the euro is to reduce the sensitivity of European consumer prices to fluctuations in the exchange rate. The introduction of the euro does not affect the pricing of goods sold by European firms in the U.S., which are set in dollar before and after the euro. Table 1 summarizes the currency in which prices are set, as well as the degree of exchange rate pass-through.

The objective of the firms is to maximize their expected discounted profits. Firms are owned by the domestic residents,[14] implying that the expected profits are evaluated using the households' contingent nominal interest rate.

Before the euro. A U.S. firm producing brand v chooses two prices, both denominated in U.S. dollars. One, $P_{11}^{dol}(v)$, is charged for domestic sales and the other, $P_{21}^{dol}(v)$, is charged for export sales. The firm chooses prices by taking its monopoly power into account, and the optimal prices are written as (all firms being identical, the v index can be omitted),

$$P_{11t}^{dol} = \frac{\lambda}{\lambda - 1} \frac{E_{t-1} W_{1t} C_{1t}^{1-\rho}}{E_{t-1} C_{1t}^{1-\rho}}; \qquad P_{21t}^{dol} = \frac{\lambda}{\lambda - 1} \frac{E_{t-1} W_{1t} C_{2t}^{1-\rho}}{E_{t-1} C_{2t}^{1-\rho}} \tag{8}$$

In general, the firm will not set prices at their certainty equivalent level ($\lambda(\lambda - 1)^{-1} E_{t-1} W_{1t}$). Focusing on the expression for P_{11t}^{dol}, (8) shows that the firm sets the unit revenue P_{11t}^{dol} as a markup over the expected unit cost $E_{t-1} W_{1t}$, weighting both by $C_{1t}^{1-\rho}$ in each state of nature. The term $C_{1t}^{1-\rho}$ captures the strength of the demand for the firm's brand, evaluated at the consumer's marginal utility of money. A high value corresponds to a state of nature where the firm has many customers and/or

[14] This is done without loss of generality: the assumption of complete markets, reflected in the optimal risk-sharing condition (4), implies that the firms' optimal choices are unaffected by the country of residence of their owners.

the firm's owner valuation of revenue is high. The intuitive interpretation of (8) is that the firm's owner does not give an equal weight to all possible states of nature when setting the price, but instead, cares more about the states where $C_{1t}^{1-\rho}$ is high. If such states happen to be states where the cost of production is low (that is, W_{1t} and $C_{1t}^{1-\rho}$ are negatively correlated so that $E_{t-1}W_{1t}C_{1t}^{1-\rho} \leq E_{t-1}W_{1t} \cdot E_{t-1}C_{1t}^{1-\rho}$) the owner will wish she could lower her price ex post in these states. As she cannot do so, she lowers the price somewhat ex ante, so that $P_{11t}^{dol} \leq \lambda(\lambda-1)^{-1}E_{t-1}W_{1t}$. The intuition underlying the optimal price for exports, P_{21t}^{dol}, is similar.

A European firm chooses two different prices. One in European currency for domestic sales, $P_{22t}^{eur}(v)$, and one in dollar for export sales, $P_{12t}^{dol}(v)$. The optimal prices can be computed as,

$$(9) \qquad P_{12t}^{dol} = \frac{\lambda}{\lambda-1}\frac{E_{t-1}S_{12t}W_{2t}C_{1t}^{1-\rho}}{E_{t-1}C_{1t}^{1-\rho}}; \qquad P_{22t}^{eur} = \frac{\lambda}{\lambda-1}\frac{E_{t-1}W_{2t}C_{2t}^{1-\rho}}{E_{t-1}C_{2t}^{1-\rho}}$$

A similar intuition can be given for the pricing equations (9) as was given for Equation (8). All firms being identical within a region, per capita employment (output) in the United States and Europe can be written from (7) as

$$(10) \qquad \begin{aligned} L_{1t} &= n\frac{P_{1t}^{dol}C_{1t}}{P_{11t}^{dol}} + (1-n)\frac{S_{12t}P_{2t}^{eur}C_{2t}}{P_{21t}^{dol}}; \\ L_{2t} &= n\frac{P_{1t}^{dol}C_{1t}}{P_{12t}^{dol}} + (1-n)\frac{P_{2t}^{eur}C_{2t}}{P_{22t}^{eur}} \end{aligned}$$

Firms sell their products directly to consumers in both countries. Obstfeld and Rogoff (2000) point that this aspect, combined with a limited pass-through of exchange rate fluctuations to consumer prices, has the counterfactual implication that a country's terms of trade improve when its currency depreciates. This counterfactual aspect can easily be removed if we introduce intermediaries that buy goods from firms and sell them to consumers.[15] We choose not to adopt such a structure to keep our model simple. Furthermore, thanks to our assumption of complete asset markets, the introduction of intermediaries has no impact on the welfare results, as Devereux et al. (1999) demonstrate.

After the euro. The introduction of the euro affects neither the prices set by European firms, nor those charged by U.S. firms for domestic sales. The only change occurs for the prices charged by U.S. firms for export sales, P_{21t}^{eur}, which are now set in euros instead of dollars. The optimal price can be computed as

$$(11) \qquad P_{21t}^{eur} = \frac{\lambda}{\lambda-1}\frac{E_{t-1}S_{12t}^{-1}W_{1t}C_{2t}^{1-\rho}}{E_{t-1}C_{2t}^{1-\rho}}$$

European employment is still given by (10), whereas U.S. employment becomes

[15] See Devereux et al. (1999) and Tille (2000).

$$L_{1t} = n\frac{P_{1t}^{dol} C_{1t}}{P_{11t}^{dol}} + (1-n)\frac{P_{2t}^{eur} C_{2t}}{P_{21t}^{eur}} \tag{12}$$

3. THE IMPACT OF THE EURO ON CONSUMPTION AND EMPLOYMENT

3.1. *Monetary Shocks and Consumption Determination.* We assume that monetary shocks are the only source of volatility in the model, and the money supply follows a random walk (with drift), so that for each region i we can write $E_t M_{it} M_{it+1}^{-1} = \mu_i$. We also consider that the money supplies follow independent, lognormal distribution.[16] Letting lowercase letters be logs, this implies that

$$m_{it+1} = m_{it} + v_{it+1}$$

where v_{it} has mean $-\ln \mu_i + 0.5\sigma_{v_i}^2$ and variance $\sigma_{v_i}^2$. In order to focus on the impact of the euro solely through the currency of pricing, we consider that the growth rate and volatility of money shocks are unaffected by the euro, and are identical in the U.S. and Europe so that $\mu_1 = \mu_2 = \mu$, and $\sigma_{v_1}^2 = \sigma_{v_2}^2 = \sigma_v^2$. As money supplies are log normal, all variables in our models follow a log normal distribution. Throughout the article, lowercase letters denote logs ($z = \ln Z$) and the variances/covariances across log variables are denoted by $\sigma_{zy} = E[zy] - E[z]E[y]$. For simplicity we assume that money shocks in Europe and the U.S. are uncorrelated: $\sigma_{v_1 v_2} = 0$.

Under these assumptions, we can show that consumption is proportional to real balances: $C_{it}^{\rho} \propto M_{it}(P_{it}^{i})^{-1}$, where $\propto$ denotes a relation of proportionality. Before the introduction of the euro, U.S. consumer prices are entirely predetermined. U.S. consumption then fluctuates only in response to U.S. monetary shocks and is completely insulated from European shocks. By contrast, European prices are affected by monetary shocks through the exchange rate pass-through on imports from the U.S., so European consumption is affected by both U.S. and European shocks:

$$C_{1t} \propto (M_{1t})^{\frac{1}{\rho}}; \qquad C_{2t} \propto \left(M_{1t}^{n} M_{2t}^{1-n}\right)^{\frac{1}{\rho}} \tag{13}$$

After the introduction of the euro, U.S. consumption is still determined by (13). European consumption is now insulated from U.S. money shocks:

$$C_{2t} \propto (M_{2t})^{\frac{1}{\rho}} \tag{14}$$

3.2. *Consumption Volatility.* The major results of the analysis are presented in Table 2. We start with the variance of log consumption in the U.S. and Europe. Before the introduction of the euro, European consumption is less volatile than U.S. consumption. This reflects the cushioning role of the exchange rate pass-through

[16] None of the main results depends on the fact that monetary shocks are independent across countries. This assumption merely simplifies the exposition.

TABLE 2

MAIN RESULTS

	Before the euro	After the euro
Consumption volatility		
United States	$\sigma_{c_1}^2 = \frac{1}{\rho^2}\sigma_v^2$	$\sigma_{c_1}^2 = \frac{1}{\rho^2}\sigma_v^2$
Europe	$\sigma_{c_2}^2 = \frac{n^2+(1-n)^2}{\rho^2}\sigma_v^2$	$\sigma_{c_2}^2 = \frac{1}{\rho^2}\sigma_v^2$
Expected consumption		
United States	$E_{t-1}C_{1t} = \Phi \exp\left[\frac{\rho-1}{2}\sigma_{c_1}^2\right] = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$	$E_{t-1}C_{1t} = \Phi \exp\left[\frac{\rho-1}{2}\sigma_{c_1}^2\right] = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$
Europe	$E_{t-1}C_{2t} = \Phi \exp\left[\frac{\rho-1}{2}\sigma_{c_2}^2 - \frac{n(1-n)}{2\rho}\sigma_{s_{12}}^2\right] = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2 - \frac{n(1-n)}{\rho}\left(1+\frac{\rho-1}{\rho}\right)\sigma_v^2\right]$	$E_{t-1}C_{2t} = \Phi \exp\left[\frac{\rho-1}{2}\sigma_{c_2}^2\right] = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$
Expected "power" consumption		
United States	$E_{t-1}C_{1t}^{1-\rho} = \Phi^{1-\rho} \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$	$E_{t-1}C_{1t}^{1-\rho} = \Phi^{1-\rho} \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$
Europe	$E_{t-1}C_{2t}^{1-\rho} = \Phi^{1-\rho} \exp\left[\left(\frac{\rho-1}{2\rho^2} + \frac{n(1-n)(1-\rho)^2}{\rho^2}\right)\sigma_v^2\right]$	$E_{t-1}C_{2t}^{1-\rho} = \Phi^{1-\rho} \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$
Employment (Output)		
United States and Europe	$E_{t-1}L_t = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right] \times \left\{1+(1-n)\left[\exp\left[\frac{n(1-n)(1-\rho)^2}{\rho^2}\sigma_v^2\right]-1\right]\right\}$	$E_{t-1}L_t = \Phi \exp\left[\frac{\rho-1}{2\rho^2}\sigma_v^2\right]$

$\Phi = \left(\frac{\lambda\eta}{\lambda-1}\right)^{-1/\rho}$

on real variables. A monetary expansion in Europe increases the nominal balances of European consumers, but it also leads to a depreciation of the European currency, which partially reduces the purchasing power of European consumers through imported inflation. This effect disappears with the introduction of the euro, as retail prices for imports from the U.S. are now set in euros so there is no exchange rate pass-through to consumers. Table 2 shows that the introduction of the euro increases the volatility of European consumption, while leaving U.S. consumption volatility unchanged.

On this measure alone, it would seem that the introduction of the euro would make Europeans worse off, while having no implications for U.S. welfare. But welfare cannot be measured only by consumption variance. This is because the stochastic properties of exchange-rate regimes also have implications for the expected values of consumption and output, as discussed in Devereux and Engel (1998). In order to do a full welfare analysis, we must therefore compute the expected values of consumption and employment.

3.3. *Expected Consumption*

3.3.1. *Before the Euro.* From the pricing equations (8)–(9), the risk-sharing relationship (4), the labor supply equation (6), and the definitions of the price index (3) we can derive a system of two relations that implicitly determine expected consumption in the U.S. and Europe. The solution of this system is given in Table 2. In both regions an increase in consumption volatility increases expected consumption when $\rho > 1$. To highlight the intuition behind this result, we point out that from labor supply (6) the nominal wage in the United States is proportional to C_{1t}^{ρ}. Then, from (8), we see that when $\rho > 1$, the marginal cost is negatively correlated with the firms' marginal utility-discounted demand $C_{1t}^{1-\rho}$, and firms set their prices below the certainty equivalent values. Since consumption is proportional to real balances, low prices result in higher consumption.

Expected consumption in Europe, however, is *negatively* related to exchange-rate volatility. For both U.S. and European producers, exchange-rate volatility increases the variance of marginal cost, given C_{2t}. This induces them to raise their prices charged for sales in Europe relative to those in the U.S. ($P_{11t}^{dol} \leq P_{21t}^{dol}$), thereby reducing expected European consumption. The presence of this additional channel in Europe therefore implies that expected consumption is lower in Europe than in the United States before the euro, as shown in Table 2.

3.3.2. *After the Euro.* After the introduction of the euro, the price of U.S. goods in Europe is given by (11) instead of (8). We can undertake a similar analysis as before to derive the expected consumptions, the result being given in Table 2. The introduction of the euro does not affect expected consumption in the United States. By contrast, the effect of exchange-rate volatility on European expected consumption disappears, as U.S. exporters now set their prices in euro. The removal of the direct impact of exchange-rate volatility reinforces the effect of the higher European consumption volatility, and the introduction of the euro boosts expected consumption in Europe.

3.4. *Expected "Power" Consumption.* The expectation of "power" consumption, which we define as $C_i^{1-\rho}$, plays a central role in the welfare analysis. Under our assumption of log-normal shocks, this term can be computed based on the volatility and expected value of consumption as

$$E_{t-1}C_{it}^{1-\rho} = (E_{t-1}C_{it})^{1-\rho} \exp\left[\frac{\rho(\rho-1)}{2}\sigma_{c_i}^2\right] \tag{15}$$

Table 2 indicates the value for the U.S. and Europe, both before and after the euro. As the euro does not affect the volatility and expected value of U.S. consumption, $E_{t-1}C_{1t}^{1-\rho}$ is the same before and after the euro. The effect on $E_{t-1}C_{2t}^{1-\rho}$ is more complex. The increase in expected consumption in Europe tends to lower $E_{t-1}C_{2t}^{1-\rho}$, as $\rho > 1$, whereas the higher consumption volatility goes the other way. Table 2 shows that the former effect is stronger and $E_{t-1}C_{2t}^{1-\rho}$ is reduced by the introduction of the euro.

3.5. *Expected Employment.* Expected employment is obtained by combining the output demands (7) and the prices (8), (9), and (11). It turns out that expected employment is the same for the United States and Europe, both before and after the euro, and is equal to a weighted average of expected "power" consumption in both countries:

$$E_{t-1}L_{1t} = E_{t-1}L_{2t} = \frac{\lambda-1}{\lambda\eta}\left[nE_{t-1}C_{1t}^{1-\rho} + (1-n)E_{t-1}C_{2t}^{1-\rho}\right] \tag{16}$$

Table 2 shows that the introduction of the euro *reduces* expected employment, in both countries. Expected employment in each region is just the sum of U.S. and European households' consumption of that region's good. Expected employment falls because expected European consumption of both goods 1 and 2 (which is proportional to $E_{t-1}C_{2t}^{1-\rho}$) falls.

At first glance this seems paradoxical; expected composite consumption in Europe rises, but expected consumption of each element in the composite falls. But it is important to remember that composite consumption is not a linear function of the consumption of each region's good. We can derive the following relation between the aggregate consumption index and the consumptions of each type of good:

$$E_{t-1}C_{2t} = \frac{1}{n^n(1-n)^{1-n}}\left(E_{t-1}C_{21t}\right)^n\left(E_{t-1}C_{22t}\right)^{1-n}\exp\left[-\frac{n(1-n)}{2}\mathrm{Var}(c_{21t}/c_{22t})\right]$$

Before the introduction of the euro, exchange-rate fluctuations affect the relative price of domestic and imported consumption, since $\mathrm{Var}(c_{21t}/c_{22t}) = \sigma_s^2$. This depresses expected composite consumption. The introduction of the euro eliminates this effect. While the expected consumption of each good falls, this is more than offset by the removal of the effects of exchange-rate volatility, so that expected composite consumption rises.

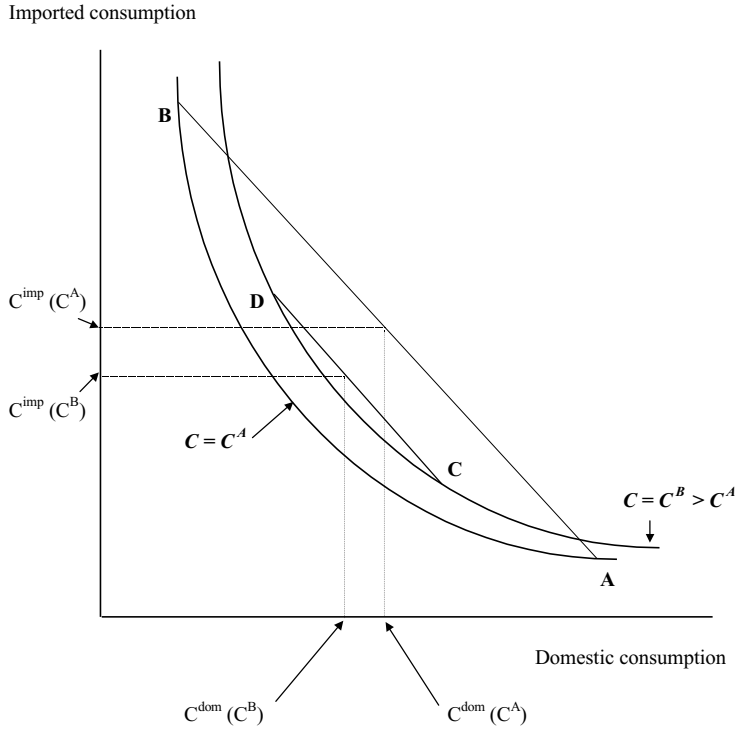

FIGURE 1

CONSUMPTION AGGREGATE

Figure 1 illustrates the point, with domestic and imported consumption on the horizontal and vertical axis, respectively. Indifference curves connect all possible pairs of domestic and imported consumption giving the same overall consumption basket. Figure 1 presents two such curves, $C = C^A$ and $C = C^B$, with C^B giving higher utility than C^A. The figure contrasts two cases. In the first case, exchange-rate volatility is large, and the economy can be either at point A or at point B, the aggregate consumption basket being equal to C^A at either point. The expected consumption of domestic and imported goods is given by $C^{dom}(C^A)$ and $C^{imp}(C^A)$ respectively. The second case is characterized by a lower exchange-rate volatility, and the economy can be at point C or at point D. At either point, the aggregate consumption basket C^B is larger than in the previous case. But the expected consumption of each good, $C^{dom}(C^B)$ and $C^{imp}(C^B)$, is smaller.

4. THE WELFARE EFFECTS OF THE EURO

We now examine the impact on welfare. Expected utility depends upon consumption, real money balances, and labor supply. But following recent literature

(e.g., Corsetti and Pesenti, 2001), we focus on the expected utility of consumption and labor supply alone, abstracting from the role of real balances.[17] The expected utility for the U.S. and Europe is given by

$$E_{t-1}U_{1t} = \Psi_1 \frac{1}{1-\rho} E_{t-1}C_{1t}^{1-\rho} - \frac{\lambda-1}{\lambda}(1-n)E_{t-1}C_{2t}^{1-\rho} \tag{17}$$

$$E_{t-1}U_{2t} = \Psi_2 \frac{1}{1-\rho} E_{t-1}C_{2t}^{1-\rho} - \frac{\lambda-1}{\lambda} n E_{t-1}C_{1t}^{1-\rho} \tag{18}$$

where $\Psi_1 = \frac{\lambda + n(\lambda-1)(\rho-1)}{\lambda} > 0$, and $\Psi_2 = \frac{\lambda + (1-n)(\lambda-1)(\rho-1)}{\lambda} > 0$.

Equation (18) shows that the introduction of the euro increases European utility as $E_{t-1}C_{2t}^{1-\rho}$ is reduced. Intuitively, the expected utility of consumption, $(1-\rho)^{-1}E_{t-1}C_{2t}^{1-\rho}$, increases and expected employment is reduced. Thus, Europeans gain on both counts. How about expected utility in the U.S.? While the expected utility of consumption in the U.S., $(1-\rho)^{-1}E_{t-1}C_{1t}^{1-\rho}$, is unchanged, the fall in expected employment must also raise expected utility in the U.S. Thus, the introduction of the euro raises welfare in both Europe and the U.S.!

Our model, therefore, shows that the introduction of the euro is not a zero-sum game in which any European gain would be mirrored by a loss for the United States. Instead, both regions benefit. Therefore, paradoxically, the role of the U.S. dollar as the world currency is actually *detrimental* for U.S. welfare, when the alternative is a world where consumer prices are stabilized in local currencies.

5. A NUMERICAL ILLUSTRATION

We now illustrate our findings by computing the magnitude of the effects on consumption, output, and welfare. In order to focus on the role of price setting, we reasonably assume that the United States and Europe have the same size ($n = 0.5$). We set the standard deviation of money shocks to 3.5% ($\sigma_v = 0.035$) and compute the effects for various values of the intertemporal elasticity of substitution for consumption, $\rho > 1$.

Figure 2 presents the welfare gain. To facilitate the interpretation of the results, we express the gain as a percentage of the gain that would result from removing monetary volatility entirely ($\sigma_v^2 = 0$).[18] We can see that the gain is quite sizable: if $\rho = 2$, the introduction of the euro brings a gain equal to 28% of the gain from

[17] We can show that taking the direct welfare effect of real balances into account has only a negligible impact on our results.

[18] The actual gains in expected consumption and reduction in expected employment are small (e.g., when $\rho = 2$, the gain in expected consumption in Europe is 0.02%, and the reduction in expected employment in Europe and the United States is 0.004%). The utility gains in this model ultimately are traced to gains from risk reduction. It is well known that expected utility models do not produce large utility losses from risk. We do not contribute to this debate. Instead, we present our welfare results as the gains relative to the elimination of all risk.

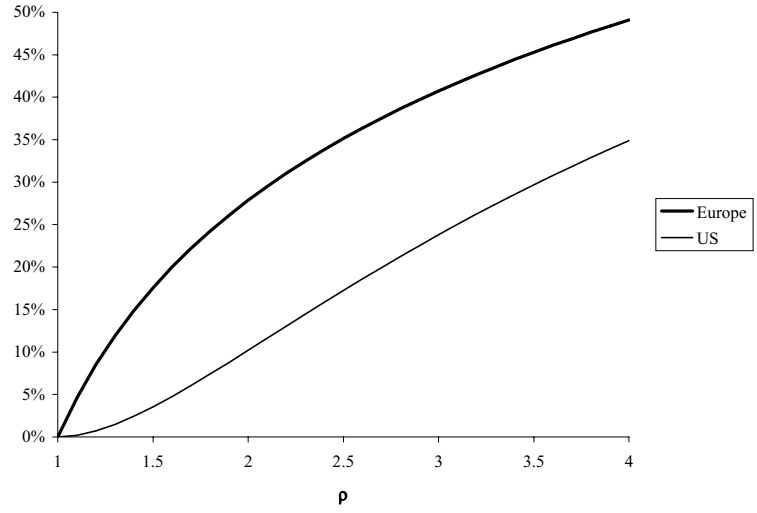

FIGURE 2

WELFARE GAIN (PERCENTAGE OF GAIN FROM REMOVING VOLATILITY)

completely removing monetary variability for Europe. The corresponding figure for the United States is 10%. The gains are even larger for higher values of ρ.

Another perspective on the welfare gain from the euro is to compute the reduction in money volatility that would bring the same welfare gain, without the euro, as the gain brought by the euro, for a given volatility. We can show that if $\rho = 2$, the benefit from the introduction of the euro for Europe is equivalent to a 15% reduction in the standard deviation of monetary shock worldwide. The corresponding figure for the United States is a 5% reduction of the standard deviation.

In an appendix available on request, we provide a sensitivity analysis of the welfare results with respect to alternative parameter values. The extent of monopoly power, as measured by the elasticity of substitution across different brands, λ, has a negligible impact. The size of the U.S., n, has a nonmonotonous impact. When n is small, a higher n significantly amplifies the welfare effects, which are largest when n is about 0.3. Further increases in the value of n then reduce the magnitude of the welfare effects.

6. DISCUSSION

Although the article is fundamentally a theoretical exercise, it is interesting to ask to what extent our results might throw light on the real-world situation of export pricing and welfare in the post-euro environment. There are two central features of our model. The first is that, pre-euro, exchange rate pass-through to the U.S. has been smaller than that for other countries (specifically for European countries). The second, more conjectural assumption, is that the growth and

acceptance of the euro is likely to decrease the extent of exchange rate pass-through to European imports. While the first issue has been widely discussed in the empirical pass-through literature, the small data sample since the inception of the euro gives us little evidence regarding the second conjecture.

A fairly commonly accepted conclusion in the empirical pass-through estimates is that there is much more local currency pricing for exports to the U.S. than exports from the U.S. Papers that support this general conclusion include Kreinin (1977), Mann (1986), Knetter (1989), Ohno (1989), Gagnon and Knetter (1995), Feenstra et al. (1996), and Clark and Faruqee (1997). In particular, Clark and Faruqee (1997) find that the volatility of (cost-adjusted) import prices, relative to nominal effective exchange-rate volatility, is far lower for the U.S. than for all other G7 countries. In a survey, Goldberg and Knetter (1997) note that the evidence suggests not only that exchange rate pass-through is higher for non-U.S. countries, but that pass-through seems to decrease with economic size. Therefore, we take these results as evidence in favor of our "pre-euro" configuration of price setting.[19]

What about the second argument of the article; the ECB's conjecture that the euro will give rise to increased "local currency pricing" of exports to Europe, and diminished exchange-rate pass-through? There is as yet insufficient evidence to support this conjecture.[20] From a theoretical standpoint, the determination of the currency of price setting is a complex problem. In Devereux and Engel (2001), it is shown that in an environment of full symmetry and complete markets (as in the current article), firms will be indifferent with respect to the currency in which they pre-set prices. This gives rise to multiple equilibria—the determination of a price-setting currency is similar to a coordination game where one currency may become the predominant one for price setting simply because all firms choose to price in this currency. This opens up a large number of possible different scenarios as to the impact of the euro, ranging from no effect at all, to rapid adjustment toward a new currency for price setting.

More generally, however, as discussed above, transactions costs due to menu changing, currency hedging, and other factors are likely to be important in determining the evolution of price setting in the euro area. Nonetheless, we feel that a reasonable view is that both empirical and theoretical arguments strongly suggest

[19] One study that is slightly at variance with this consensus is Knetter (1993). Some of his estimates suggest that differences in exchange-rate pass-through are greater across industries than across countries. But data limitations lead Knetter's pass-through elasticities to be estimated very imprecisely, making hypothesis testing difficult. When industries are aggregated, he does find that there is more pricing to market in exports to the U.S., than in exports by the U.S.

[20] In an interesting recent article, Hau et al. (2000) provide some rather surprising results on the development of the euro as an international currency. They show that the euro bid–ask spreads increase relative to the analogous bid–ask spreads in the German mark prior to the setting up of the currency union. Though this might seem counterintuitive, given the belief that the euro will play the role of an internationally accepted currency, they provide a micro-structural explanation of the observations, based on financial market transition effects following the closing down of intra-European currency markets. It is not obvious whether these results have any immediate relationship to the question of currency of price setting and exchange-rate pass-through, however.

that the increased size of the euro area market is likely to decrease the sensitivity of the HICP to fluctuations in the euro exchange rate.

7. CONCLUSION

This article has shown that the introduction of the euro could have important positive and normative effects for both Europe and the rest of the world. In the case where the euro causes a change in the retail pricing of U.S. imports in Europe, our central conjecture, the advent of the euro causes a rise in the expected value of consumption in both the U.S. and Europe, and a rise in welfare.

We can expand our setup in several directions.[21] A first alternative is to assume that U.S. firms have to set identical dollar prices for their goods in the pre-euro area, $P_{11}^{dol} = P_{21}^{dol}$. This does not affect our result that the introduction of the euro benefits both Europe and the U.S. A second extension is to assume that intra-European exchange rates are flexible in the pre-euro area. The introduction of the euro then brings even larger benefits for Europe as it entails a beneficial pegging of intra-European exchange rates. A final variant is to assume that instead of inducing U.S. firms to set their export prices in euros, the introduction of the euro leads European firms to set their export prices in dollars. The introduction of the euro can then be shown to be detrimental for both countries.

There are substantial additional implications of the euro that could be explored within the same type of model. Clearly, a substantial change in the currency of pricing may have important business cycle consequences. Betts and Devereux (1999) show how changes in price setting can alter international macroeconomic transmission in substantial ways. In addition, our analysis focuses on monetary shocks for brevity and can be extended to fiscal and technology shocks. In addition, the extent to which exchange-rate fluctuations are passed-through to consumer prices is taken as exogenous. An interesting extension will be to endogenize this dimension of the model in a tractable way. The main point that we wish to make in this article is that there may be important and previously unforeseen consequences of the European single currency, when we take the potential impact on exchange-rate pass-through to consumer prices into account.

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[21] The detailed analysis can be found in Devereux et al. (1999).

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