New Keynesian Explanations of Cyclical Movements in Aggregate Inflation and Regional Inflation Differentials

by

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Abstract

What determines the cyclical behavior of aggregate inflation and regional inflation differentials? The answer has strong implications for monetary policy and in Europe for the Stability and Growth Pact. In the United States, inflation rates move pro-cyclically, and across the Euro Area, inflation differentials are positively correlated with growth differentials. This suggests that demand shocks are the primary determinants of the cyclical behavior of aggregate inflation and regional inflation differentials. In this paper, we discuss New Keynesian explanations of these correlations, and we argue that demand shocks are either missing or inadequately modeled in the in typical New Keynesian model.

Key Words: inflation, inflation differentials, NNS models

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Traditional Keynesian explanations of the cyclical movements of inflation focused primarily on demand shocks. An increase in say government spending was thought to have multiplier effects on consumption and output, and the increase in aggregate demand would eventually create inflation (via the Phillips Curve) and an increase in the interest rate (via the central bank's monetary policy rule). U.S. data appear to be consistent with this view: recent VAR studies suggest that consumption rises in response to a government spending shock, and that the Federal Funds Rate rises in response to the increase in output and inflation;[1] moreover, the unconditional correlation between inflation and output is positive (0.33), and so is the correlation between nominal interest rates and output (0.35).[2] Recent data from the Euro Area also appear to be consistent with the traditional Keynesian view: national inflation differentials are positively correlated with national growth differentials (a fact we will document below).

The Real Business Cycle (RBC) model that followed focused primarily on productivity shocks. In the RBC view, productivity shocks drive fluctuations in output, while the cyclical behavior of interest rates and inflation is simply the manifestation of a monetary policy that is otherwise irrelevant. More recently, a New Neoclassical Synthesis (NNS) adds monopolistic competition and nominal inertia to the RBC model to create a new Keynesian model in which both

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[1] Fatas and Mihov (2001a ,b), Blanchard and Perotti (2002) and Canzoneri, Cumby and Diba (2002) find that an increase in government spending increases consumption and output; Canzoneri, Cumby and Diba (2002) also find that the Federal Funds rate reacts in a manner that is consistent with standard Henderson-McKibbin-Taylor rules. On the other hand, Perotti (2004) suggests that the effect on consumption may have diminished in recent years, and he questions whether it exists at all in some European countries.

[2] For HP-filtered quarterly U.S. data from 1960.1 to 2003.2, the correlation between CPI inflation and the log of GDP is 0.33; the correlation between the Federal Funds Rate and the log of GDP is 0.35. These correlations do not change sign for leads or lags of one quarter. See the appendix of CC&D for data sources.

productivity shocks and demand shocks play a role in the cyclical movements of interest rates and inflation.[3] In NNS models, demand shocks tend to produce procyclical movements in interest rates and inflation, while productivity shocks tend to produce countercyclical movements.

In this paper, we analyze standard NNS models to see if they are capable of generating the procyclical movements of interest rates and inflation that are observed in the data. We begin with a model developed in Canzoneri, Cumby and Diba (CC&D) (2004). The CC&D model captures some key features of the U.S. business cycle, but as we shall see it generates strongly negative correlations between interest rates and output, and between inflation and output. We attribute this model failure to the fact that – despite the presence of shocks to government purchases and the interest rate rule – productivity shocks play a dominant role in the determination of inflation: variance decompositions indicate that productivity shocks explain 95% of the fluctuations in inflation in the CC&D model. We suspect that some demand side shocks are either absent or incorrectly modeled, and we investigate both possibilities in this paper.

We begin by augmenting the CC&D model with a private spending shock that has been suggested by Ireland (2004), Gali and Rabanal (2004) and others. Private spending shocks – like government spending shocks – produce procyclical movements in interest rates and inflation, and this increases the unconditional correlations of interest rates and inflation with output. However,

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[3] Goodfriend and King (1997) outlined the New Neoclassical Synthesis, and gave it the name. Woodford (2003) provides a masterful introduction to this class of models. NNS models are now being used widely in the academia and at policy making institutions. Important early contributions to the study of monetary policy include Rotemberg and Woodford (1997), King and Wolman (1999), and Erceg, Henderson and Levin (2000). Recent extensions to include fiscal policy include Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004). Larger institutional models include the Bank of England's BEQM (see Bank of England (2004)), the IMF's GEM (see Bayoumi et al (2004)), and the FRB's SIGMA (see Erceg et al (2004)); similar models are being developed at the ECB and a number of other central banks.

private spending shocks are modeled as shocks to preferences, and – unlike government spending shocks – they are not directly observable: it is unclear how large we can plausibly make them. In the CC&D model, for standard deviations consistent with the existing literature, the unconditional correlations of interest rates and inflation with output remain negative.

For this reason, we go on to investigate the possibility that the propagation of fiscal shocks is incorrectly modeled in the typical NNS model. The CC&D model is Ricardian in the sense that households respond to an increase in government spending (and the implied increased tax burden) by working more and spending less, in apparent contradiction to the VAR studies cited earlier. This raises the possibility that a government spending shock has less effect on aggregate demand in the model than it does in the U.S. economy. Galì, López-Salido and Vallés (2004) have shown that adding "rule of thumbers" – households that just consume their income each period – can make aggregate consumption rise in response to an increase in government spending.[4] Here, we add rule of thumbers to the CC&D model to see if we can generate the procyclical movements in inflation and interest rates that are observed in the data.

The CC&D model describes a single country with a single aggregate production sector. In this paper, we extend the CC&D model to a two country currency union, and we investigate its explanation of the cyclical behavior of the national inflation differentials.

The early experience of the Euro has generated interest in explanations of national inflation differentials. Differences between national inflation rates and the Euro area average are proving to

[4] Some of the larger institutional models employ a similar device.

be larger than many had anticipated.[5] Figure 1 illustrates the average inflation differentials since the Euro's inception;[6] they range from a high of 1.8% p.a. in Ireland to a low of - 0.6% p.a. in Germany. These inflation differentials are also quite volatile; for example, the standard deviation of the inflation differential between France and Germany is 1.6% p.a.

We are not aware of any rigorous analysis of the welfare consequences of these inflation differentials, but the way in which they are being viewed seems to depend upon what is thought to be generating them. When the differentials are thought to be driven by unstable fiscal policies, then the presumption seems to be that the Stability and Growth Pact may be useful in controlling them. When the differentials are thought to be driven by other national or regional demand disturbances, then the presumption seems to be that the Stability and Pact is getting in the way of automatic stabilizers embodied in national fiscal policies. And finally, when the differentials are thought to be driven by asymmetric productivity shocks, the presumption seems to be that the differentials reflect relative price movements that do not need to be corrected. While a rigorous welfare analysis is well beyond the scope of this paper, it is clearly of interest to ask what is driving the inflation differentials, both in the data and in the NNS models that are currently being used to evaluate policy.

Figure 1 illustrates what might be described as a cross-sectional Phillips Curve for the Euro

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[5] ECB (2003) documents these inflation differentials. Altissimo, Benigno and Rodriguez Palenzuela (2004) provide an interesting statistical decomposition of the inflation differentials. See also Duarte (2003) and Angeloni and Ehrmann (2004).

[6] Quarterly inflation differentials for country J are computed as $4(\log(P_{J,t}/P_{J,t-1}) - \log(P_{E,t}/P_{E,t-1}))$, where $P_{J,t}$ is the average over the three months of quarter t of the HIPC for country J and $P_{E,t}$ is similarly defined for the Euro Area. Real growth differentials are computed similarly by taking annualized averages of quarterly growth rates of real GDP and subtracting the annualized average quarterly growth rate for the Euro Area. The source for both the HIPC and real GDP data is Eurostat.

area: average HICP inflation differentials are positively correlated with average GDP growth differentials; the correlation is 0.69. This positive correlation has in fact been rather well documented in the recent literature. Similar graphs appear in Angeloni and Ehrmann (2004) and Duarte (2003), and Chart 16 in ECB (2003) illustrates a positive correlation between average HICP inflation and cumulative output gaps. In addition, the time series correlations appear to be consistent with the cross sectional correlations; for example, the correlation between French and German inflation and growth differentials is 0.58. All of these correlations seem to suggest that the inflation differentials are being driven by demand shocks of some sort, and not by productivity shocks.

What drives regional inflation differentials in the new NNS models? There is not yet a large literature on this, but initial results suggest that regional inflation differentials in the Euro area are driven by productivity shocks. Duarte and Wolman (2002) and Altissimo, Benigno and Rodriguez-Palenzuela (2004) developed small two-country NNS models to study inflation differentials in a monetary union.[7] Duarte and Wolman found that productivity shocks alone were enough to explain the observed volatility in the French-German inflation differential, and that the volatility of the model's inflation differential was little affected by the addition of government spending shocks. Altissimo, Benigno and Rodriguez-Palenzuela found that fiscal shocks played a very minor role in their model's variance decomposition for national inflation. It is unclear however that either of these NNS models would be capable of generating the positive correlations illustrated in Figure 1 or by the French and German time series data.

Here, we extend the original CC&D model to a two-country model of a currency union,

[7] Their models are more elaborate than the CC&D model in that they incorporate service and manufacturing sectors; they are less elaborate than the CC&D model in that they do not incorporate endogenous capital formation or Calvo-style wage setting.

loosely calibrated to French and German data. We find that it is not capable of generating the correlations illustrated in Figure 1 or by the French and German time series data. Once again, we attribute this failure to the dominant role played by productivity shocks in the determination of inflation. And once again, we add private spending shocks and "rule of thumbers" to see if we can make the model generate the positive correlations found in the data.

The rest of the paper proceeds as follows: Section 1 outlines the basic framework we use in all of our models. Section 2 discusses the failure of the closed economy model to explain the pro-cyclical movements in interest rates and inflation that are observed in the U.S. data. Section 3 adds non-Ricardian elements to the closed economy model in an attempt to make the model more consistent with the data. Section 4 discusses the failure of the currency union model to explain the correlations shown in Figure 1 and the French and German time series data. Section 5 adds non-Ricardian elements to the currency union model in an attempt to make the model consistent with those correlations. Section 6 concludes.

1. A Framework that Encompasses All Four Models

In this paper we analyze four models: Ricardian and non-Ricardian versions of a closed economy calibrated to the U.S., and Ricardian and non-Ricardian versions of a two-country currency union (very roughly) calibrated to the larger countries in the Euro area. In this section, we develop a general framework that encompasses all four models.

The general framework includes a home country (designated by H) and a foreign country (designated by F). In each country, monopolistically competitive firms and workers set their prices and wages in standard Calvo contracts; and in each country, CES aggregators show how the differentiated products and labor services are valued. At the top of the pyramid, CES aggregators show how the two aggregate national products are valued for consumption and investment. Households own the capital stocks in each country and rent them to firms in their own country; so capital is freely mobile within a country, but immobile across countries. Govern-ments in each country levy taxes on sales, capital and labor, and governments make lump sum transfers (which may be negative) to households. The two countries share a common currency.

More specifically, home and foreign firms, indexed by $f_H \in [0, 1]$ and $f_F \in [0, 1]$, produce differentiated goods that are aggregated into national products:

$$Y_J = [\int_0^1 Y_J(f_J)^{(\sigma-1)/\sigma} df_J]^{\sigma/(\sigma-1)}, \quad J = H, F \tag{1}$$

where $\sigma > 1$. (Time subscripts will be suppressed when there is little chance for confusion.) The producer price indices are

$$P_J = [\int_0^1 P_J(f_J)^{1-\sigma} df_J]^{1/(1-\sigma)}, \quad J = H, F \tag{2}$$

and the demands for the individual firms' products are

$$Y_J^d(f_J) = (P_J/P_J(f_J))^{\sigma} Y_J, \quad J = H, F \tag{3}$$

where Y_J is aggregate demand for the national product.[8]

Home and foreign consumption goods are CES aggregates of the two national products:

$$C = [\mu^{1/\eta} C_H^{(\eta-1)/\eta} + (1-\mu)^{1/\eta} C_F^{(\eta-1)/\eta}]^{\eta/(1-\eta)} \tag{4}$$

$$C^* = [\mu^{*1/\eta} C^*_F{}^{(\eta-1)/\eta} + (1-\mu^*)^{1/\eta} C^*_H{}^{(\eta-1)/\eta}]^{\eta/(1-\eta)}$$

where $\eta > 1$, C_H (C^*_H) is home (foreign) consumption of home output, C_F (C^*_F) is home (foreign) consumption of foreign output, and μ and $\mu^* \in [½, 1]$ measure the degree of home bias in

[8] The modeling of monopolistic competition in NNS models is now standard; for a more detailed discussion, see Canzoneri, Cumby and Diba (2003).

consumption. The national CPI's are

$$P = [\mu P_H^{1-\eta} + (1-\mu)P_F^{1-\eta}]^{1/(1-\eta)} \quad (5)$$

$$P^* = [(1-\mu^*)P_H^{1-\eta} + \mu^* P_F^{1-\eta}]^{1/(1-\eta)}$$

Note that if we eliminate the home bias (by setting $\mu = \mu^* = ½$), then the home and foreign consumption goods will be identical, and there will be no CPI inflation differentials.[9]

Home and foreign investment goods are also CES aggregates of the two national products:

$$I = [\mu_I^{1/\eta} I_H^{(\eta-1)/\eta} + (1-\mu_I)^{1/\eta} I_F^{(\eta-1)/\eta}]^{\eta/(1-\eta)} \quad (6)$$

$$I^* = [\mu_I^{*1/\eta} I^{*(\eta-1)/\eta}_F + (1-\mu_I^*)^{1/\eta} I^{*(\eta-1)/\eta}_H]^{\eta/(1-\eta)}$$

where I_H (I^*_H) is home (foreign) investment demand for home output, I_F (I^*_F) is home (foreign) investment demand for foreign output, and μ_I and $\mu_I^* \in [½, 1]$ measure the degree of home bias in investment. Home and foreign investment good prices are

$$P_I = [\mu_I P_H^{1-\eta} + (1-\mu_I)P_F^{1-\eta}]^{1/(1-\eta)} \quad (7)$$

$$P_{I*} = [(1-\mu_I^*)P_H^{1-\eta} + \mu_I^* P_F^{1-\eta}]^{1/(1-\eta)}$$

Home and foreign households, indexed by $h_H \in [0, 1]$ and $h_F \in [0, 1]$, supply differentiated labor services that are aggregated into national labor services:

$$N_J \equiv [\textstyle\int_0^1 L(h_J)^{(\phi-1)/\phi} dh_J]^{\phi/(\phi-1)}, \quad J = H, F \quad (8)$$

where $\phi > 1$. Labor, like capital, is mobile within a country, but immobile across countries. The price of this composite labor service to the firms of country J is:

[9] The alternative (and more cumbersome) way of modeling inflation differentials would be to introduce non-traded goods and the familiar Balassa-Samuelson effect, whereby productivity gains in the traded sector cause a real appreciation, or an increase in the CPI inflation differential in a currency union. We doubt, however, that adding a non-traded sector would change our main point that productivity gains have precisely the opposite effect. As Altissimo, et al. (2004) point out, the Balassa-Samuelson appreciation is smaller than the real depreciation resulting from the terms of trade effect in reasonably calibrated models.

$$W_J = [\int_0^1 W(h_J)^{1-\phi} dh_J]^{1/(1-\phi)}, \quad J = H, F \tag{10}$$

and the demand for the individual household's labor service is

$$L(h_J) = (W/W(h_J))^{\phi} N_J, \quad J = H, F \tag{11}$$

where N_J is the aggregate demand for the national labor service.

The production technology in each country is Cobb-Douglas:

$$Y(f_J) = Z_J K(f_J)^{\nu} N(f_J)^{\nu-1}, \quad J = H, F \tag{12}$$

where total factor productivity, Z_J, is common to all of the firms in country J; Z_J is governed by a stochastic process that will be described below. As is well known (and discussed in CC&D), aggregate production functions can be written as

$$Y_J \ (\equiv [\int_0^1 Y_J(f_J)^{(\sigma-1)/\sigma} df_J]^{\sigma/(\sigma-1)}) = \int_0^1 Y_J(f_J) df_J / DP_J = Z_J K_J^{\nu} N_J^{1-\nu} / DP_J, \quad J = H, F \tag{13}$$

$$DP_J \equiv \int_0^1 (P(f_J)/P_J)^{-\sigma} df_J, \quad J = H, F \tag{14}$$

where the DP_J are measures of price dispersion in the two countries.

The staggered price setting in each country follows the familiar Calvo pattern. In any given quarter, each firm in country J (= H, F) gets to reset it price with probability $1-\alpha_J$. The first order conditions for a firm that gets to reset its price, and resulting equations for aggregate price dynamics, are now well known in the literature; we do not need to repeat them here.[10]

Utility in period t for a Home household is[11]

$$U_t(h_H) = E_t \sum_{s=t}^{\infty} \beta^{s-t} [\log(C_s(h_H)) - (1+\chi)^{-1} L_s(h_H)^{1+\chi}] \tag{15}$$

Households have access to a complete contingent claims market. A Home household's budget constraints are

[10] They are described in some detail in CC&D.

[11] Foreign households are modeled symmetrically.

$$E_s[\Delta_{s,s+1}B_{s+1}(h_H)] + (1+\tau_{H,c})\, P_sC_s(h_H) + P_{I,s}I_s(h_H) = (1-\tau_{H,w})W_s(h_H)L^d{}_s(h_H) \qquad (16)$$

$$+ (1-\tau_{H,k})R_{H,s}K_{H,s-1}(h_H) + \delta\tau_{H,k}P_{I,s}K_{H,s-1}(h_H) + TR_{H,s} + B_s(h_H) + D_s(h_H)$$

where (using Woodford's compact notation) $E_s[\Delta_{s,s+1}B_{s+1}(h_H)]$ is the price of a portfolio of state contingent claims and $B_s(h_H)$ is the payoff in period s; $D_s(h_H)$ are dividends. The first two terms on the RHS of (16) are the household's after tax labor and rental income; $R_{H,s}$ is the rental rate on capital and $K_{H,s-1}(h_H)$ is the household's capital stock at the beginning of the period. The next term repre-sents a simple rendition (following Erceg et al. (2004)) of depreciation allowances for the tax on capital. $TR_{H,s}$ is a lump sum transfer (or tax, if negative); the distortionary tax rates, $\tau_{H,c}$, $\tau_{H,w}$, and $\tau_{H,k}$, are assumed to be constant. The household's capital accumulation constraint is

$$K_s(h_H) = (1 - \delta)K_{s-1}(h_H) + I_s(h_H) - \tfrac{1}{2}\psi[(I_s(h_H)/K_{s-1}(h_H)) - \delta]^2K_{s-1}(h_H) \qquad (17)$$

where the last term is a capital adjustment cost, and δ is the rate of depreciation. The household chooses $C_t(h_H)$, $L_t(h_H)$, $W_t(h_H)$, $I_t(h_H)$ and $B_{t+1}(h_H)$ to maximize (15) subject to the demand for its labor services, (11), and the constraints (16) and (17).

Our assumption of complete contingent claims markets has the implication that the marginal utility of nominal wealth will equalize across households in both countries. This means that all households in a given country will make the same decisions about consumption and investment, and that the aggregate and individual values of these variables will be identical in equilibrium.[12] In addition, there will be complete consumption risk sharing across countries:[13]

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[12] For example, $C \equiv \int_0^1 C(h_H)dh_H = C(h_H)\int_0^1 dh_H = C(h_H)$. Canzoneri, Cumby and Diba (2003, 2004) discuss the household's first order conditions and the implications of complete contingent claims market in some detail.

[13] The constant ξ depends on initial conditions, and upon factors like relative tax rates, if the rates are known when the contingent claims market meets. The value of ξ plays no role in our analysis since we use first order approximations around a non-stochastic steady state.

$$(1+\tau_c)P_tC_t = \xi(1+\tau^*_c)P^*_tC^*_t \tag{18}$$

The market clearing conditions for the two national products are

$$Y_{H,t} = C_{H,t} + C^*_{H,t} + I_{H,t} + I^*_{H,t} + G_t \tag{19}$$

$$Y_{F,t} = C_{F,t} + C^*_{F,t} + I_{F,t} + I^*_{F,t} + G_t^* \tag{20}$$

where G_t and G_t^* are home and foreign government purchases; we assume complete home bias in government consumption.

2. A Closed Economy Model with Ricardian Equivalence

In this section and the next, we explore the implications of our closed economy models for the cyclical behavior of the interest rate and inflation. The Ricardian Closed Economy (RCE) model is identical to the CC&D model.

2.1. The RCE model.

The RCE model emerges from the general framework outlined in Section 1 if we eliminate the foreign country, set the home bias parameters (μ and μ_I) equal to one, and set the distortionary tax rates ($\tau_{H,c}$, $\tau_{H,w}$, and $\tau_{H,k}$) equal to zero. Lump sum taxes finance government spending, and the model exhibits Ricardian equivalence.

The RCE model is calibrated to U.S. data, and estimated stochastic processes explain the behavior of monetary policy, government spending, and total factor productivity. A detailed discussion of the calibration process, estimation procedures and data sources can be found in Appendix B of CC&D.

A Henderson-McKibbin-Taylor rule describes monetary policy; our estimate of the rule is:

$$i_t = 0.222 + 0.824i_{t-1} + 0.35552\pi_t + 0.032384(\text{output gap})_t + \epsilon_{i,t}, \tag{21}$$

where $\pi_t = \log(P_t/P_{t-1})$ and the standard deviation of the interest rate shock, $\epsilon_{i,t}$, is 0.00245. CC&D used nonlinear least squares to estimate this rule over the Volcker and Greenspan years (1979.3 - 2003.2). For estimation purposes, CC&D defined the output gap to be actual GDP minus the Congressional Budget Office's 'potential' GDP (both in logs); in numerical solutions of the model, we replace potential output with the steady state output.[14]

CC&D used a longer sample period (1960:1 - 2003:2) to estimate the productivity process:

$$\log(Z_t) = 0.923\log(Z_{t-1}) + \epsilon_{p,t} \tag{22}$$

where $\log(Z_t)$ is the deviation of total factor productivity from an estimated linear trend, and the standard deviation of the productivity shock, $\epsilon_{p,t}$, is about 0.009.

CC&D also estimated an auto regressive process for government spending:

$$\log(G_t) = \Gamma + 0.973\log(G_{t-1}) + \epsilon_{g,t}, \tag{23}$$

where the standard error of the fiscal shock, $\epsilon_{g,t}$, is about 0.01. Estimates over the two sample periods (1979.3 - 2003.2 and 1960:1 - 2003:2) were quite similar. In our model simulations, we choose the intercept term, Γ, to make $G/Y = 0.20$ in the steady state.

The other parameters used to calibrate the RCE model are given in Table 1. The Frisch labor supply elasticity, $1/\chi$, is low by RBC standards, but high by the standards of the empirical labor literature; CC&D find that its value does not matter much for the ability of the model to fit the data. The values for α and ω imply that prices are fixed for three quarters on average, and wages are fixed for four quarters on average. The values for σ and ϕ imply that price and wage markups are about 17%. The value of ψ is chosen to make the volatility of investment match that in the data.

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[14] A natural alternative would be to use the flexible wage/price level of output. However, CC&D found that the model's simulated output gap more closely resembled the output gap in the data with the specification we use here.

2.2 Inflation and interest rates in the RCE Model.

CC&D showed that the RCE model is capable of explaining several key characteristics of the U.S. business cycle.[15] Table 2 compares results from the calibrated model with quarterly data from the U.S. economy. The model's variables are expressed as log deviations from a deterministic steady state. The U.S. data are also in logs, and both the model data and the actual data have been HP-filtered. We used Dynare (see Juillard (2003)) to calculate the model's steady state, to find a first order approximation, and to calculate the moments reported in Table 2. Beginning with the row for GDP, 0.014 is the model's standard deviation of output, which is slightly smaller than the standard deviation in the data, 0.016. Proceeding to the row for consumption, 0.839 is the ratio of the standard deviation of consumption to the standard deviation of output in the model, and 0.962 is the correlation between consumption and output. These are close to the corresponding statistics in the data. The next three rows provide the same statistics (standard deviations relative to the standard deviation of output and correlations with output) for investment, hours worked and real wages.

The RCE model comes fairly close to matching the data for all these variables, though real wages and output are more positively correlated in the model than they are in the data. Impulse response functions from the model (not pictured) show that productivity shocks make the real wage move procyclically, while the other shocks make them move countercyclically. This is our first indication that productivity shocks may be playing an inordinate role in the RCE model, or equivalently that some demand side shocks may be either absent or incorrectly modeled.

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[15] The model is not capable of capturing the persistence found in U.S. data; it does not include the elements Christiano, Eichenbaum and Evans (2005) find necessary to do so.

The rows for inflation and the nominal interest rate do alert us to some weaknesses in the RCE model. The volatility of inflation in the model is less than it is in the data. But even more alarming is the fact that both the interest rate and inflation are negatively correlated with output in the model, while they are positively correlated in the data.

Where are these model failures coming from? Figure 2 reports the model's impulse response functions (IRFs) for output, inflation and the nominal interest rate. These IRFs suggest that productivity shocks make inflation and the interest rate move countercyclically, while government spending shocks make inflation and the interest rate move procyclically. The interest rate shock makes inflation move procyclically, but of course the interest rate itself moves countercyclically. The model's variance decompositions – reported in Table 3 – show which of these shocks matter the most. Productivity shocks explain more than 90% of the variation in inflation and about 50% of the variation in output; interest rate shocks do move output, but they have little effect on inflation; and government spending shocks do almost nothing to either variable. Productivity shocks are clearly the most important factor in the cyclical behavior of inflation, and this would appear to account for the model's counterfactual negative correlations.

This suggests that the RCE model may be missing some demand shocks, or that the demand shocks that have been included may not have been modeled correctly. The IRFs in Figure 3 suggest that the government spending shocks may not have been modeled correctly. An increase in government spending crowds out consumption as well as investment. This is a familiar result from the RBC literature: the increased tax burden causes optimizing households to work more and consume less. Adding nominal inertia does not change this Ricardian type of response. But, as Fatas and Mihov (2001a, b) have noted, this response in consumption is at odds with several recent VAR studies.[16] This suggests that government spending shocks may not have as much effect on aggregate demand in the model as they do in the U.S. economy, and that this may be why the model fails to predict procyclical movements in inflation. We explore this possibility in the next section. But before going on, we check the robustness of our results to different assumptions about nominal rigidity, and we investigate the possibility that an alternative demand shock – one suggested by Ireland (2004) and Galì and Rabanal (2004) – may help the model explain the cyclical behavior interest rates and inflation.

2.3 The Importance of Nominal Inertia

Some NNS models assume wages are flexible; indeed, Goodfriend and King (2001) and others have argued that the observed rigidity of nominal wages may not even be allocative. And of course, the RBC model did not have any nominal inertia. For these reasons, we test the robustness of our results to different assumptions about the type and degree of nominal inertia.

If we let wages be flexible ($\omega = 0$, $\alpha = 0.67$) in the RCE model, the correlation of inflation and output improves slightly (compared to the benchmark case reported in Table 2): it rises from -0.389 to -0.204. If we let both wages and prices be flexible ($\omega = \alpha = 0$), the correlation is slightly worse: it falls from -0.389 to -0.429. The correlation between the interest rate and output is virtually the same, -0.998, in all of these cases. So, no matter what we assume about the type or degree of nominal inertia, the benchmark RCE model seems quite incapable of generating the positive correlations that are observed in the U.S. data.

2.4 Adding a Private Spending Shock to the RCE Model.

Ireland (2004), Galì and Rabanal (2004) and others have added what might be viewed as a

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[16] See footnote 1.

private spending shock to NNS models; the household utility function becomes:

$$U_t(h) = E_t\sum_{s=t}^{\infty} \beta^{s-t}[a_s\log(C_s(h)) - (1+\chi)^{-1}L_s(h)^{1+\chi}] \quad (24)$$

where a_s is a preference shock. Both Ireland (2004) and Galì and Rabanal (2004) model a highly persistent shock; we let:

$$\log(a_t) = 0.9\log(a_{t-1}) + \epsilon_{a,t} \quad (25)$$

where the standard deviation of the innovation, $\epsilon_{a,t}$, is 0.03. We chose this value to be large enough to make the standard deviation of output in the model match the standard deviation of output in the data; our choice happens to coincide with Ireland's (post 1980) estimate.

Figure 2 shows the model's IRFs for the private spending shock. As expected, the shock makes inflation and the interest rate move procyclically, and this might be expected to help with the model's unconditional correlations. Table 4 reports the model's variance decompositions. The private spending shock moves both output and the interest rate, but it has little effect on inflation. The model's unconditional correlations do rise, but not to the positive levels observed in the data: the correlation between inflation and output rises from -0.389 (as reported in Table 2) to -0.218, and the correlation between interest rate and output rises from -0.998 to -0.686.

We could increase the unconditional correlations further by raising the standard deviation of the private spending shock. We should note, however, that this is already a very volatile shock: its standard deviation is three times the standard deviation of the government spending shock. The private spending shock – unlike the government spending shock – is not directly observable, since it is modeled as a shock to household preferences. So, we have no direct way of measuring its volatility. We have followed standard practice in choosing the parameter to help the model match second moments in the data – here the standard deviation of output.[17] And, as stated earlier, our choice coincides with Ireland's (2004) estimate. We conclude that the private spending shock suggested by Ireland (2004) and Galì and Rabanal (2004) is a step in the right direction, but it does not resolve the problem fully.

3. A Closed Economy Model with Departures from Ricardian Equivalence

In this section, we investigate the possibility that the government spending shocks do not propagate correctly in the RCE model, and that this might be the source of the counterfactual correlations the model exhibits. We add several non-Ricardian elements to the model, some of which are designed to augment the effect of a government spending shock on private consumption, and aggregate demand; our discussion of the IRFs in Figure 2 suggested that this was an experiment worth trying. First, we describe our modifications of the RCE model; then, we explore their implications for the correlations in question.

3.1 The NRCE Model

We add two types of non-Ricardian elements to the RCE model to arrive at what we will call the Non-Ricardian Closed Economy (NRCE) Model. First, we add distortionary taxation: taking average tax rates for the U.S. from Table 2 of Carey and Rabesona (2002), we set $\tau_c = 0.064$, $\tau_w = 0.234$, and $\tau_k = 0.273$. And second, we add what Galì, López-Salido and Vallés (2003) call "rule of thumb consumers", or what we will think of as "liquidity constrained" households.

More specifically, the NRCE model has two types of households. Optimizing households

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[17] Estimating the full model – say with Bayesian methods – would not resolve the issue. This would just be a more formal way of choosing the standard deviation of the shock to match the moments in the data.

(denoted by an O) are like the households we have already modeled; we do not need to change the equations that describe their behavior (except to add an O subscript to the relevant variables). Liquidity constrained households (denoted by an L) hold no assets; they simply consume their disposable incomes each period.

We have a number of choices to make in our modeling of L households, and these choices do affect the way in which aggregate household consumption responds to an increase in government spending. Generally, our choices will err on the side of making the response of aggregate consumption large. This gives the model the best chance of explaining the procyclical movements in interest rates and inflation.

The first set of choices has to do with the importance of L households in the economy. We assume that the population of L households is equal to the population of O households (each having a unit mass), but we let the L households be less productive than O households. L households supply a homogeneous labor service, and the composite labor input entering the production functions (12) becomes

$$N_t = [\zeta N_{O,t}^{(\eta-1)/\eta} + (1 - \zeta)N_{L,t}^{(\eta-1)/\eta}\,]^{\eta/(\eta-1)} \tag{24}$$

where $\eta > 0$ and $0.5 < \zeta < 1$. $N_{O,t}$ is the aggregate labor input (defined by (8)) of O households and $N_{L,t}$ is the labor input of L households. The aggregate wage rate for this composite labor input is

$$W_t = [\zeta^{\eta}\, W_{O,t}^{1-\eta} + (1 - \zeta)^{\eta}\, W_{L,t}^{1-\eta}\,]^{1/(1-\eta)} \tag{25}$$

where $W_{O,t}$ is given by (10). We follow Erceg et. al. (2004) in assuming that the wages of L households are proportional to the aggregate wage of O households, but we make the constant of proportionality less than one (since L households are less productive). Specifically, we let

$$W_{L,t} = [(1 - \zeta)/\zeta]W_{O,t} \tag{26}$$

where $0.5 < \zeta < 1$. Then, firms' cost minimization implies that $N_{L,t} = N_{O,t}$.

In our simulations, we set $\zeta = 0.6$, making $W_{L,t} = (2/3)W_{O,t}$; the steady state share of aggregate consumption going to L households about 40 percent. Campbell and Mankiw (1989) estimated that the rule of thumbers' share of consumption is between 40 and 50 percent, but our value of 40 percent is quite high when compared to more recent estimates reported by Coenen and Straub (2004), Heathcote (2005) and Reis (2004). Clearly, our choice of a large consumption share for L households enhances the non-Ricardian effects on consumption that we are trying to model.

L households consume their disposable incomes:

$$(1 + \tau_{c,t})C_{L,t} = (1 - \tau_{w,t})(W_{L,t}/P_t)N_{L,t} + TR_{L,t} \qquad (27)$$

where $TR_{L,t}$ are government transfers. Since we assume that both types of households have unit mass, aggregate consumption in the NRCE model is

$$C_t = C_{O,t} + C_{L,t} \qquad (28)$$

The stock of real government debt, D_t, evolves according to the budget constraint

$$D_t = (1 + i_{t-1}) D_{t-1}/\pi_t + G_t + TR_{O,t} + TR_{L,t} \qquad (29)$$

$$- \tau_{c,t}C_t - \tau_{w,t}(W_{O,t}N_{O,t} + W_{L,t}N_{L,t})/P_t - \tau_{H,k}[(R_{H,t} - \delta P_{I,t})/P_t]K_{H,t-1}$$

where $TR_{O,t}$ is a lump sum transfer to (or tax on) O households. Letting D/Y represent the debt to GDP ratio in the steady state, the government's spending and transfer policies are

$$\log(G_t) = \Gamma_g + 0.973\log(G_{t-1}) - \rho_g(\log(D_{t-1}/Y_t) - \log(D/Y)) + \epsilon_{g,t} \qquad (30)$$

$$\log(TR_{L,t}) = \Gamma_{trl} + 0.9\log(TR_{L,t-1}) - \rho_{trl}(\log(D_{t-1}/Y_t) - \log(D/Y)) \qquad (31)$$

$$\log(TR_{O,t}) = \Gamma_{tro} \qquad (32)$$

where $\rho_g > 0$ and $\rho_{trl} > 0$. The responses of government spending and transfers to the national debt – measured by ρ_g and ρ_{trl} – stabilize public debt dynamics. We set the intercept terms – Γ_g, Γ_{trl} and

Γ_{tro} – so that G/Y = 0.20, C/Y = 0.67 and D/Y = 0.34 in the steady state; these steady state ratios seem appropriate for the U.S. economy.

The next set of choices we have to make has to do with the strength of the fiscal response to a change in the level of debt: big values of ρ_g and ρ_{trl} enhance the non-Ricardian effects on consumption that we are trying to model. A bigger value of ρ_{trl} shifts the tax burden associated with an increase in government spending away from O households and onto L households; this limits the Ricardian consumption response of O households, and magnifies the effect of an increase in government spending on aggregate consumption. Similarly, a larger value of ρ_g implies lower government spending in the future, and this lowers the tax burden on O households.

In our simulations, we set $\rho_g = \rho_{trl} = 0.125$, and here again we may have erred on the side of making the non-Ricardian effect on consumption large. Using annual data from 1975 - 2001, we regressed the HP-filtered log of real transfers and government purchases on a constant, a lagged dependent variable, and the lagged HP-filtered log of the debt-to-GDP ratio. The values for ρ_G and ρ_{trl} computed from U.S. data are -0.075 (0.028) and -0.050 (0.059). The corresponding values computed by pooling the Euro Area countries are -0.054 (0.030) and -0.087 (0.043).[18] Thus, our values of 0.125 are about one standard error above our estimates for the U.S. data.

3.2 Inflation and interest rates in the NRCE Model.

Figure 3 shows IRFs for government spending shocks in both of the models. As noted in the last section, government spending shocks produce procyclical movements in inflation and the interest rate in the RCE model. But, they crowd out both consumption and investment and have a

[18] Similar regressions for taxes (in the U.S. or in Europe) fail to find any significant response of taxes to the level of the debt. All data are taken from the OECD.

relatively weak effect on aggregate demand; as mentioned above, the effect on consumption runs counter to some recent VAR studies. In the NRCE model, government spending shocks still crowd out both consumption and investment; in fact, we have not been able to make consumption rise for reasonable parameterizations of the NRCE model.[19] However, the crowding out of consumption is an order of magnitude smaller here, and the increase in aggregate demand (or output) is about 3.5 times larger. So, the non-Ricardian modifications of the RCE model do seem to be having the intended effect.

Variance decompositions are reported in Table 5, and they seem somewhat encouraging. Comparing Table 5 with Table 2, government spending shocks now appear to have a measurable effect on movements in output, inflation and the interest rate; however, the numbers are still quite modest. The basic message from Table 2 seems to carry over to the NRCE model: productivity shocks still explain more than 90% of the variation in inflation, and roughly half the variation in output and the interest rate; and interest rate shocks still explain rather little of the variation in inflation. Productivity shocks would still be expected to play the dominant role in determining the cyclical behavior of inflation and the interest rate; and indeed, the NRCE model's unconditional correlation between inflation and output is -0.281, and the unconditional correlation between the interest rate is -0.707. The correlations in the NRCE model are less negative than they were in the RCE model (see Table 2), but they are nowhere near the positive correlations observed in the U.S.

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[19] Eliminating the gap term in the interest rate rule (21) makes monetary policy less restrictive and allows consumption to rise. But we see little justification in this, given that the coefficient on the output gap in our estimated rule is highly significant; moreover, the gap term is well established in the empirical literature. Similarly, larger values of ρ_g and ρ_{trl} allow consumption to rise; given the uncertainty about these parameters, this may be a more promising avenue to pursue.

data. This suggest that the modeling of demand shocks may still be inadequate.

4. A Currency Union Model with Ricardian Equivalence

In this section and the next, we explore two country extensions of our NNS models; the basic question is whether our models can explain the positive correlation between inflation differentials and growth differentials illustrated in Figure 1. We begin with a Ricardian model in this section, and proceed to a non-Ricardian model in the next section. First, we explain how the Ricardian Currency Union (RCU) model emerges from the basic framework developed in Section 1.

4.1 The RCU Model

The RCU model emerges naturally from the general framework outlined in Section 1. We set the home bias parameters in consumption and investment (μ and μ_I) equal to 0.75 and 0.50 respectively. These parameter values make the steady state imports about 25% of GDP, which is roughly in line with the import shares of France and Germany. And in the Ricardian version of the model, we set the distortionary tax rates ($\tau_{H,c}$, $\tau_{H,w}$, and $\tau_{H,k}$) equal to zero; lump sum taxes finance government spending.

A serious modeling of the Euro Area is well beyond the scope of the present paper, but we do calibrate the two symmetric countries in our currency union with countries like France and Germany in mind. The correlation between inflation differentials and growth differentials in France and Germany from 1999 through 2004 is 0.58, which is very close the cross sectional correlation illustrated in Figure 2;[20] the standard deviation of the inflation differential is 0.0038. These statistics appear to be representative for the Euro Area.

[20] The (HIPC) inflation and growth differentials are quarterly, and they were HP filtered.

Our calibration of the productivity process is (roughly) based on Collard and Dellas (2002), who estimated a bivariate process using French and German data. We assume

$$\begin{bmatrix} \log(Z_{H,t}) \\ \log(Z_{F,t}) \end{bmatrix} = \begin{bmatrix} 0.76 & 0.10 \\ 0.10 & 0.76 \end{bmatrix} \begin{bmatrix} \log(Z_{H,t-1}) \\ \log(Z_{F,t-1}) \end{bmatrix} + \begin{bmatrix} \varepsilon_{Hp,t} + \varepsilon_{cp,t} \\ \varepsilon_{Fp,t} + \varepsilon_{cp,t} \end{bmatrix} \tag{33}$$

where ϵ_{cp} is a common shock (with standard deviation 0.0050) and ϵ_{Hp} and ϵ_{Fp} are country specific shocks (with standard deviation 0.0082).[21] Our calibration of the government spending processes is also based on Collard and Dellas' (2000) estimates for France and Germany. We assume

$$\log(G_{J,t}) = \Gamma + 0.94\log(G_{J,t-1}) + \epsilon_{Jg,t}, \quad J = H, F \tag{34}$$

where Γ is chosen to make the steady state G/Y ratio equal to 0.22, and the standard deviation of the innovation term set at 0.02.[22] It should be noted that this standard deviation is twice the size of the standard deviation for the U.S. government spending process; so, the currency union models have relatively large demand shocks, even without any private spending shocks.

We assume that the common monetary policy can be described by an interest rate rule without an output gap term:[23]

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[21] The autoregressive coefficients are averages of the Collard and Dellas estimates; the eigenvalues of the coefficient matrix are nearly identical to those computed from their estimates. The volatilities of the country specific productivity shocks are the averages of the two estimated by Collard and Dellas. The volatility of the common productivity shock is chosen to match the correlation of 0.37 (between the innovations of French and German productivity) implied by the Collard and Dellas estimates.

[22] The autoregressive coefficient and the standard deviation are averages of the Collard and Dellas estimates for France and Germany.

[23] We have not tried to estimate an interest rate rule for the ECB since there are fewer than six years of data. Given the primacy of inflation in the ECB's mandate, we have omitted the gap term, and we have used standard values for the response to the lagged interest rate and inflation. We also note that eliminating the gap term enhances the effect of government spending shocks on aggregate demand; see footnote 18.

$$i_t = -\log(beta)(1 - 0.8) + 0.8i_{t-1} + 2(1 - 0.8)\pi_t \quad (34)$$

where $\pi_t = 0.5\pi_{H,t} + 0.5\pi_{F,t}$ is the aggregate inflation rate, and $\pi_{H,t}$ and $\pi_{F,t}$ are the rates of growth in the national CPIs (defined by (5)). Equal weights are used to define aggregate inflation since the Home and Foreign countries are symmetric.

We have omitted an interest rate shock in (34) since it would not affect either the inflation differential or the growth differential. Only asymmetric shocks affect the variables of interest in our symmetric two-country model. They include the asymmetric productivity shocks, the government spending shocks (since government spending falls exclusively on the national product), and the asymmetric private spending shocks (which will be discussed later in this section).

4.2 Inflation Differentials and Growth Differentials in the RCU Model

Figure 4 shows the IRFs from the RCU model. Inflation differentials are defined as Home CPI inflation minus Foreign CPI inflation; growth differentials are defined as Home output growth minus Foreign output growth. As might be expected, asymmetric productivity shocks produce a negative correlation between inflation and growth differentials. An increase in Home productivity lowers Home marginal cost and inflation, and raises home output; the interest rate falls since aggregate inflation falls. In fact, productivity shocks produce a perfect negative correlation between relative prices and relative output.[24] So, asymmetric productivity shocks will make it difficult for

[24] It should be noted that our assumption of complete international risk sharing does not play a direct role in generating this correlation. Individual consumers and firms in the model minimize expenditures on the CES indexes (4) and (5). Expenditure minimization induces an inverse relationship between relative prices and relative quantities at the individual level, and aggregation does not alter this perfect negative correlation unless we let government purchases fall entirely on home goods or add shocks to (4) and (6), as we will in Section 4.4. The correlation we highlight here is closely related to the correlation between the terms of trade and output discussed in the RBC literature [e.g., Backus, Kehoe, and Kydland (1995)].

the RCU model to explain the positive correlation observed in the French and German data. On the other hand, an increase in Home government spending creates a positive inflation differential and a positive growth differential. And the central bank raises the interest rate in response to the increase in aggregate inflation.

So, once again, demand shocks (represented here by government spending shocks) appear to work in the right direction for explaining the positive correlations observed in the French and German data (and in Figure 1), while productivity shocks appear to work in the other direction. And, once again, the problem is that the variance decompositions reported in Table 6 show that productivity shocks are more important than government spending shocks in explaining the movements of these two variables. Asymmetric productivity shocks explain more than 90% of the movements in the inflation differential, and almost 25% of the movements in the growth differential. Government spending shocks do move the growth differential, but they have very little effect on the inflation differential. So, productivity shocks would be expected to play the dominant role in the correlation between the inflation differential and the growth differential. And indeed, the RCU model's unconditional correlation is - 0.32; it is far from the positive correlations observed in the French and German data (0.58) or in the cross country data in Figure 1 (0.69).

One might speculate that demand shocks are either missing or incorrectly specified in the RCU model. Another indication of this is that the standard deviation of the inflation differential in the RCU model is only 0.0016; the standard deviation of the inflation differential between France and Germany is 0.0038. In other words, the RCU model explains only half of the volatility that is observed in the data.[25]

IRFs for a government spending shock are shown in Figure 5. An increase in Home government spending raises Home output, but crowds out Home consumption.[26] In the next section, we add features to the model that accentuate the effect of an increase in government spending on private consumption. But before going on, we check the robustness of our results to different assumptions about nominal rigidity and the elasticity of demand for the Home and Foreign goods, and we investigate the possibility that an asymmetric private demand shock may help the model explain the positive correlation between inflation and growth differentials that is observed in the data.

4.3 The Importance of Nominal Inertia and the Elasticity of Substitution

In the RCU model, the type and degree of nominal inertia do seem to matter. If we let wages be flexible ($\alpha = .67$, $\omega = 0$), the correlation between inflation and growth differentials falls from -0.33 (in the benchmark case) to -0.58. And if we let both prices and wages be flexible ($\alpha = \omega = 0$), the correlations falls even further to -0.88. In terms of matching the correlations in the data, the RCU model performs better (albeit not very well) with both price and wage rigidity.

The elasticity of substitution between Home and Foreign goods is given by η in the final consumption good aggregator (4). We have been setting $\eta = 1.5$, which is consistent with what is found in both the RBC and NNS literatures. The newer trade literature has been using much higher

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[25] Duarte and Wolman (2002) found that productivity shocks alone were able to explain the volatility of the French and German inflation differential. We do not know what accounts for the difference in our results, but our model is different than theirs in a number of ways. Our model is more elaborate than theirs in that we have Calvo wage setting and endogenous capital formation; theirs is more elaborate than ours in that they have non-traded sectors.

[26] All variables in Figure 5 are Home variables. The rise in Home investment is curious, and may be counterfactual as well. The increase in government spending raises demand for Home goods, and causes a real appreciation that makes foreign investment goods less expensive.

values. But if we let η = 5 in the RCU model, the correlation between inflation and growth differentials falls from -0.33 (in the benchmark case) to -0.73. Increasing the elasticity of substitution means that larger relative price movements are required in response to relative supply shocks, and this does not help the RCU model explain the positive correlations in the data.

4.4 Adding Private Preference Shocks to the RCU Model.

In Section 2, we added the private spending shock suggested by Ireland (2004) and Galì and Rabanal (2004) to the RCE model. Here, we model the private spending shocks as shocks to the home bias preference parameters:

$$\mu_t = 0.75s_{H,t},\ \ \mu_{I,t} = 0.5s_{H,t},\ \ \mu^*_t = 0.75s_{F,t},\ \ \mu^*_{I,t} = 0.5s_{F,t} \tag{34}$$

where

$$\log(s_{J,t}) = 0.9\log(s_{J,t-1}) + \epsilon_{Js,t} \quad J = H, F \tag{35}$$

In the steady state (where $s_{J,t} = 1$), the home biases remain at their benchmark values: $\mu = \mu^* = 0.75$ and $\mu_I = \mu^*_I = 0.5$. A positive Home private spending shock ($s_{H,t} > 1$) raises the biases in the Home country. Figure 4 shows the IRFs for this shock; as expected, it produces a positive correlation between inflation and growth differentials.

We choose the standard deviation of the innovations, $\epsilon_{Js,t}$, to make the standard deviation of the inflation differential in the RCU model equal to the standard deviation the inflation differential for France and Germany. Since this requires a doubling of the standard deviation of the inflation differential, the required shocks are very big: the standard deviation of the $\epsilon_{Js,t}$ is about 1.75 times the standard deviation of the $\epsilon_{Jg,t}$, the innovations in government spending processes, and the European government spending processes were already quite volatile in comparison with the U.S.

Since the private spending shocks are so large, they play an absolutely dominant role in the variance decompositions reported in Table 7. The private spending shocks explain more over 80% of the variation in the inflation differential, and virtually all the variation in the growth differential. So, not surprisingly, the model's unconditional correlation between inflation and growth differentials rises dramatically. In fact, the correlation in the model rises to 0.57, which is almost identical to the correlation observed for France and Germany.

This might be viewed as a modeling success, but the variance decompositions in Table 7 may raise questions. The positive correlation between inflation and growth differentials was achieved by modeling a highly volatile demand shock. As noted in Section 2, we have no direct way of measuring the standard deviation of an unobserved preference shock like this. We have followed standard practice in choosing the parameter to help the model match a standard deviation in the data – here the standard deviation of the inflation differential for France and Germany. But since the shock is not observable, it is hard to know exactly what it represents, or how to gauge its empirical realism. We suspect that the shock is standing in for a number of structural shocks that have not been modeled, and for the way they propagate through aggregate demand to inflation. Once again, we conclude that the private spending shock we have modeled is a step in the right direction, but we think that more work needs to be done to identify the missing demand shocks.

5. A Currency Union Model with Departures from Ricardian Equivalence

In this section, we investigate the possibility that the government sector has not been modeled correctly in the RCU model, and that this might be the source of its (counterfactual) negative cor-relation between inflation and output differentials. We modify the model to include Non-Ricardian elements that are designed to enhance the effect of a government spending shock on consumption, and thus aggregate demand. First, we describe the modifications that are needed; then, we discuss their implications for the correlation between inflation and growth differentials.

5.1 The NRCU Model

Our description here can be very brief, as the modifications are essentially the same as those discussed in Section 3.1. We add two types of non-Ricardian elements to the RCU model to arrive at what we will call the Non-Ricardian Currency Union (NRCU) Model. First, we add distortionary taxes: taking average tax rates for the EU-15 from Table 2 in Carey and Rabesona (2002), we set $\tau_c = 0.178$, $\tau_w = 0.380$, and $\tau_k = 0.287$. And, second, we add "liquidity constrained" households. This is done in the much same way as in Section 3.1. However, we choose parameters to make G/GDP = 0.23 and debt/GDP = 0.60 in the steady state; these ratios are more representative of countries in the Euro Area.

5.2 Inflation Differentials and Growth Differentials in the NRCU Model.

Figure 5 shows IRFs for government spending shocks in both the Ricardian model and the Non-Ricardian model. As noted in the last section, government spending shocks produce a positive correlation between inflation and growth differentials. But, in the RCU model, they crowd out consumption and have a relatively weak effect on aggregate demand. In the NRCE model, government spending shocks increase consumption and have a bigger impact on aggregate demand.[27] So, once again, the modifications of the Ricardian model seem to be having the intended effect.

Variance decompositions for the NRCU model are reported in Table 7, and they are somewhat encouraging. Comparing Table 8 with Table 6, government spending shocks and productivity

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[27] Adding an output gap term to the interest rate rule attenuates the effect on consumption. For example, the rule in equation (21) implies the increase in consumption is about half the size, and only lasts 3 quarters.

shocks play a more balanced role, with government spending shocks have a big effect on growth differentials and productivity shocks having a big effect on inflation differentials. But in the end, productivity shocks still play the dominant role; the correlation between inflation differentials and growth differentials is - 0.13, about what it was in the original RCU model.

6. Conclusion

In this paper, we investigated the ability of simple NNS models to capture stylized facts about the cyclical behavior of inflation and nominal interest rates. All of our models include monopolistic wage and price setting, Calvo style nominal inertia, and endogenous capital formation. In that sense, they are representative of the NNS paradigm.

The first set of stylized facts come from the U.S. data: interest rates and inflation are positively correlated with output. However, inflation and interest rates are negatively correlated with ouput in our Ricardian Closed Economy Model. We blamed this model failure on the dominance of productivity shocks, as evidenced by the model's variance decompositions. We tried adding private spending shocks, and we tried adding "rule of thumb" households to enhance the effect of government spending shocks on private consumption. Both of these experiments seemed to be steps in the right direction, but neither innovation seemed to resolve the problem fully.

The second set of stylized facts come from the early Euro experience: national inflation differentials are positively correlated with national growth differentials; this is seen in the cross sectional data presented in Figure 1 and in the French and German time series data. However, inflation differentials are negatively correlated with output differentials in our Ricardian Currency Union Model. Once again, we blamed this model failure on the dominance of productivity shocks.

We tried adding private spending shocks, and we tried adding "rule of thumb" households to enhance the effect of government spending shocks on private consumption. And once again, both of these experiments seemed to be steps in the right direction, but neither innovation seemed to resolve the problem fully.

In the introduction, we noted that it is a matter of some concern in the Euro Area whether national inflation differentials are being driven by productivity shocks or by uncoordinated fiscal policies. If they are being driven by fiscal policies, then there may be a case for constraints like the Stability and Growth Pact; if they are being driven by productivity shocks, then there may be no need for such constraints. Initial results from the new NNS models seem to indicate that the inflation differentials are being driven by productivity shocks. However, our analysis shows that it may be difficult for a model driven by productivity shocks to explain the positive correlation between in-flation and growth differentials observed in the data. In our view, this promising new paradigm needs more work before it can give useful advice on such matters.

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Figure 1: Inflation and Growth Differentials
1999-2004, Correlation = 0.69

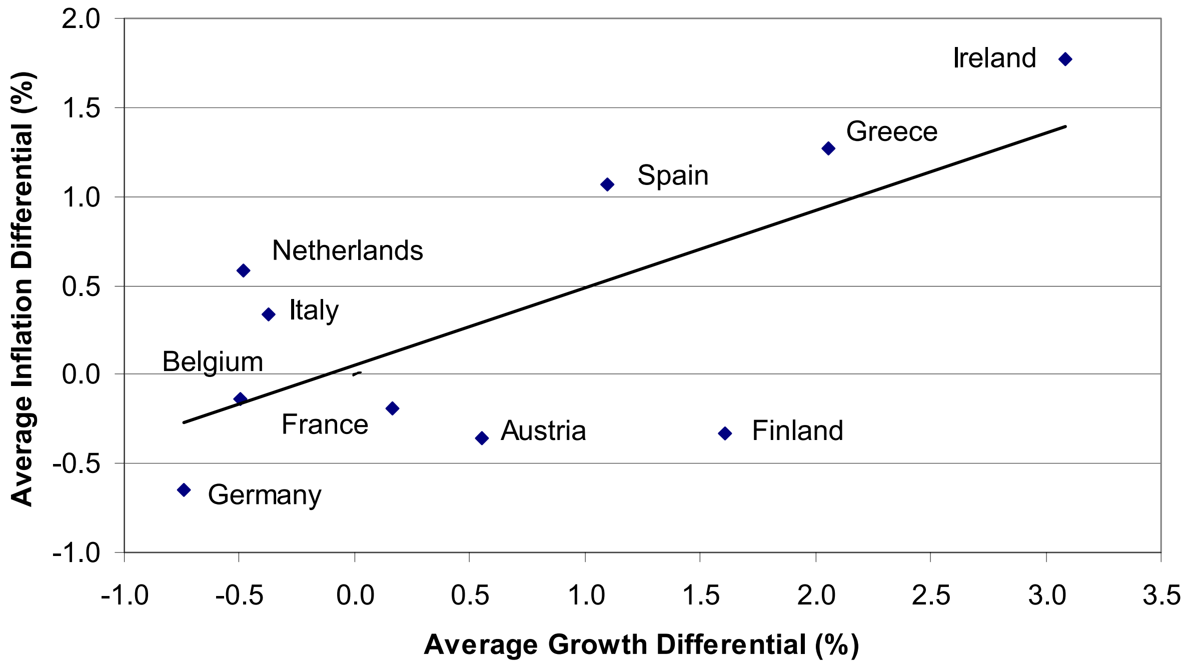


Figure 2: Impulse Responses from the RCE Model

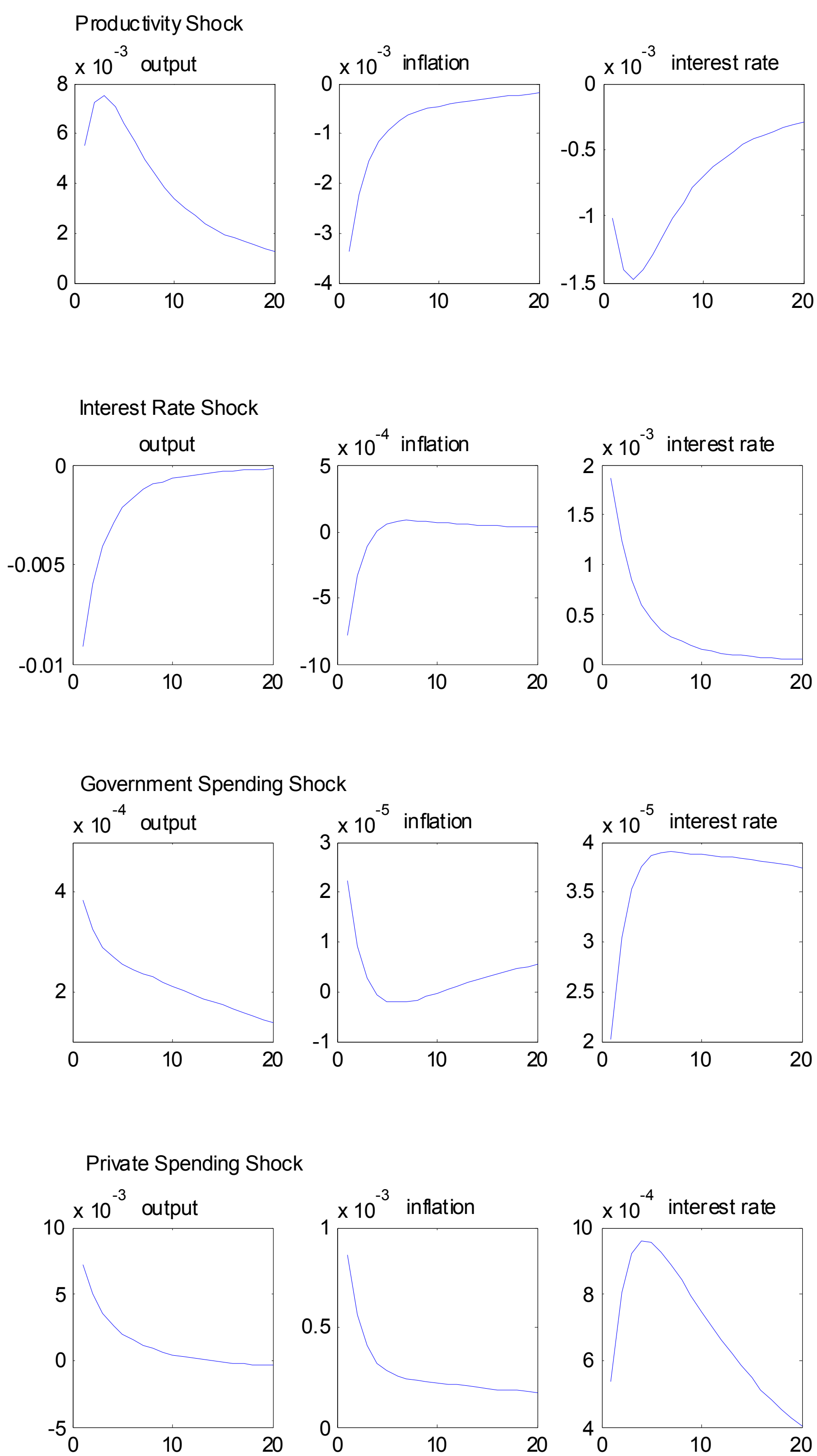
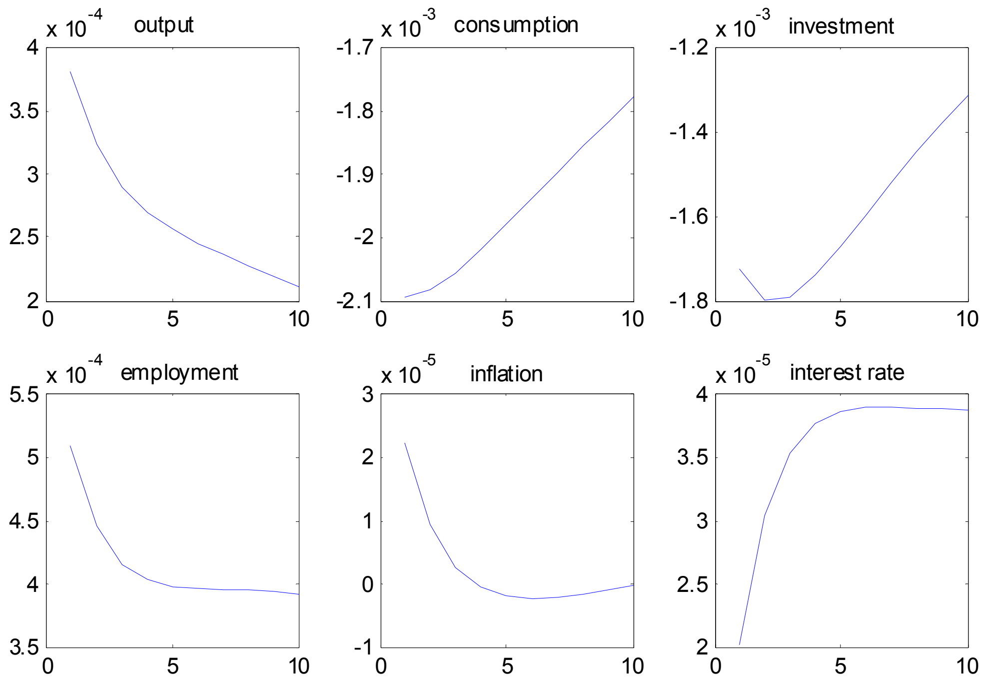


Figure 3: Government Spending Shocks in the RCE and NRCE Models

RCE Model –



NRCE Model –

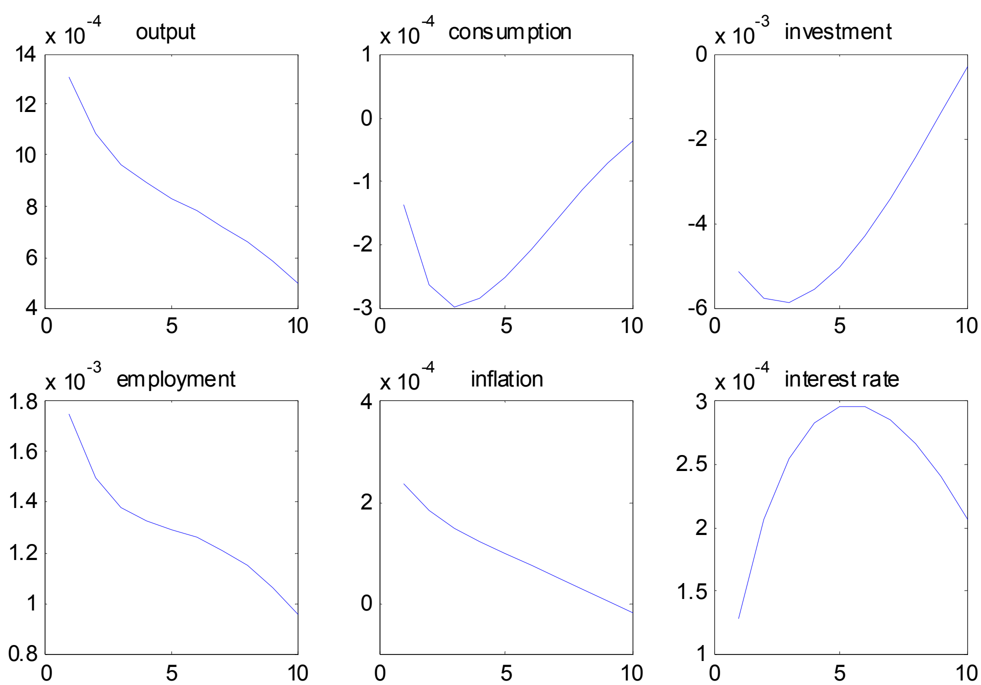


Figure 4: Impulse Responses from the RCU Model

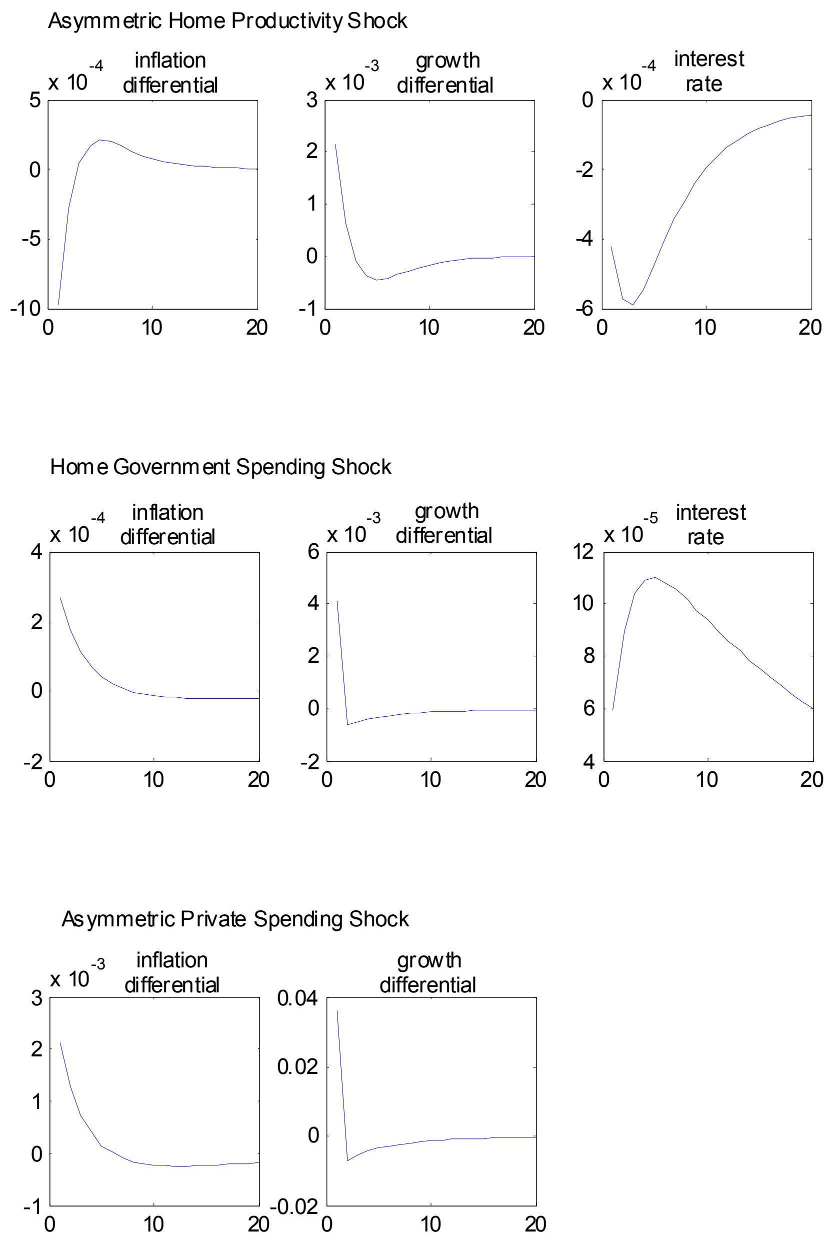
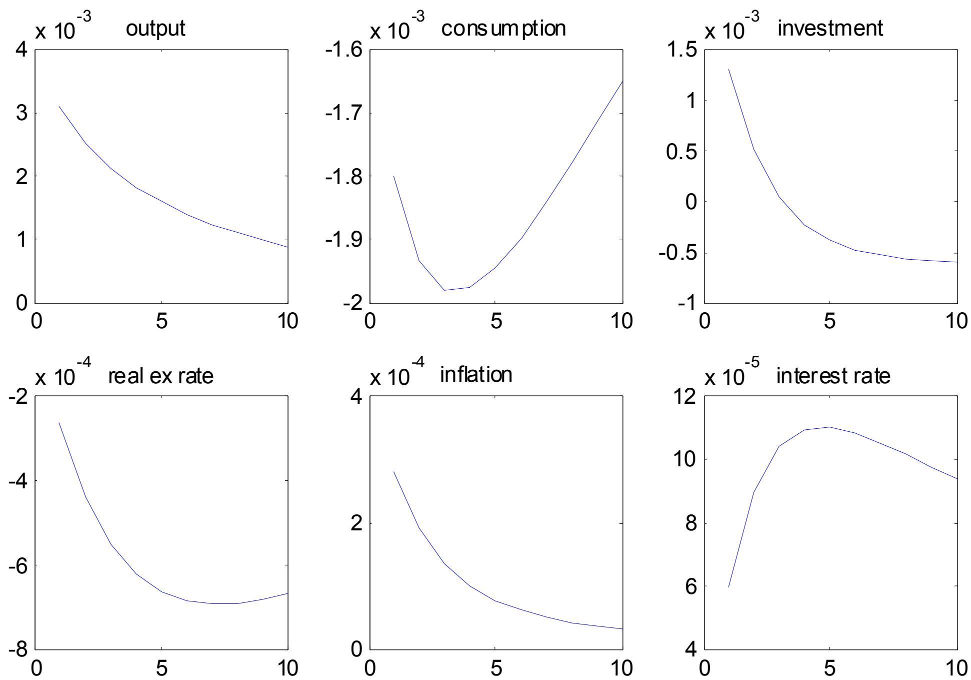


Figure 5: Government Spending Shocks in the RCU and NRCU Models

RCU Model –



NRCU Model –

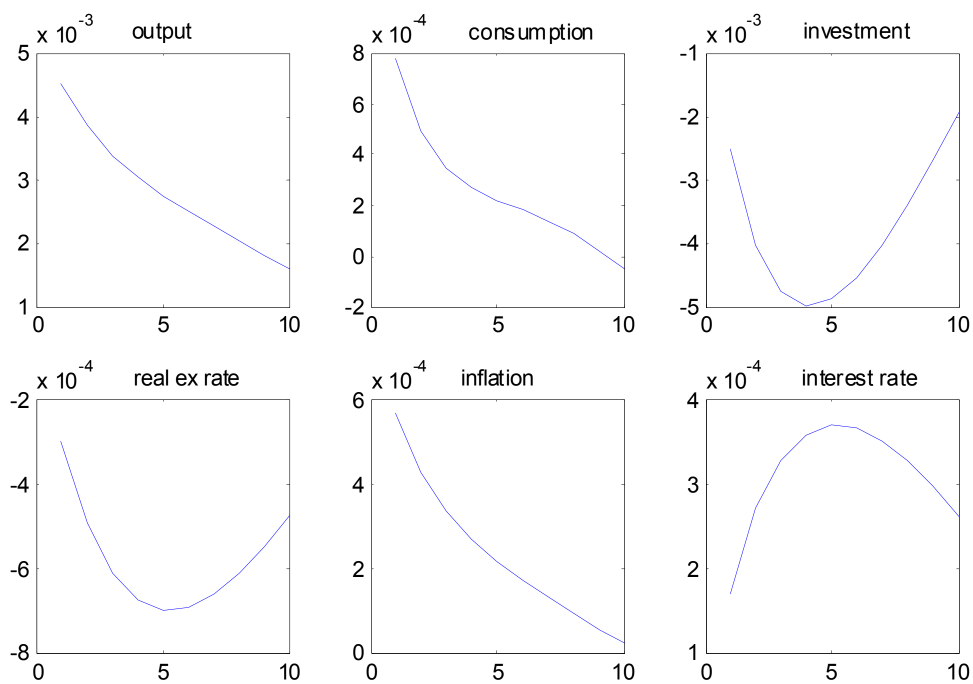


Table 1: Parameters for the Benchmark Calibration of the RCE

$1/\chi$	α	ω	σ	ϕ	δ	ψ	ν	β
0.33	0.67	0.75	7	7	0.025	8	0.25	0.99

Table 2: Benchmark Calibration of the RCE Model

STD / COR	RCE Model	actual data
GDP	0.014 1.000	0.016 1.000
Consumption	0.839 0.962	0.799 0.871
Investment	3.133 0.992	3.122 0.893
Hours	0.972 0.635	0.894 0.857
Real wage	0.497 0.553	0.470 0.243
Inflation	0.259 -0.389	0.357 0.330
Interest rate	0.203 -0.998	0.253 0.333

Notes:
1. Model data and actual data are in logarithms, and have been HP-filtered.
2. Model data was generated by Dynare, using 1st order approximations.
3. Actual data are computed using a sample of 1960:1 to 2003:2.
4. Standard deviations for the GDP row are the first number in each cell. For other rows standard deviations relative to standard deviation of output are the first numbers in each cell.
5. As both hours and the real wage are for the nonfarm business sector, we normalize their standard deviations by the standard deviation of real GDP of the nonfarm business sector.
6. Correlations with GDP are the second number in each cell.

Table 3: Variance Decompositions for the benchmark RCE Model (infinite horizon, in percent)

	productivity shock	interest rate shock	G - spending shock
GDP	52.30	47.60	0.10
inflation	94.94	5.06	0.00
interest rate	49.59	50.38	0.02

Table 4: Variance Decompositions for the RCE Model with Preference Shocks (in percent)

	productivity shock	interest rate shock	G - spending shock	P - spending shock
GDP	39.67	36.11	0.07	24.15
inflation	89.92	4.79	0.00	5.29
interest rate	41.76	42.43	0.02	15.79

Table 5: Variance Decompositions for the NRCE Model (in percent)

	productivity shock	interest rate shock	G - spending shock
GDP	50.2	45.2	4.6
inflation	92.4	5.4	2.2
interest rate	42.5	48.5	9.0

Table 6: Variance Decompositions for the RCU Model (in percent)

	combined asymmetric productivity shocks	combined government spending shocks
growth differential	23.6	76.4
inflation differential	92.5	7.5

Table 7: Variance Decompositions of the RCU Model with Preference Shocks (in percent)

	asymmetric productivity shocks	government spending shocks	private spending shocks
growth differential	0.4	1.2	98.4
inflation differential	16.2	1.3	82.5

Table 8: Variance Decompositions for the NRCU Model (in percent)

	combined asymmetric productivity shocks	combined government spending shocks
growth differential	13.5	86.5
inflation differential	88.3	11.7