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Macroeconometric Equivalence, Microeconomic Dissonance, and the Design of Monetary Policy

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Macroeconometric Equivalence, Microeconomic Dissonance, and the Design of Monetary Policy

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Abstract

Many recent studies in macroeconomics have focused on the estimation of DSGE models using a system of loglinear approximations to the models' nonlinear equilibrium conditions. The term *macroeconometric equivalence* encapsulates the idea that estimates using aggregate data based on first-order approximations to the equilibrium conditions of a DSGE model will not be able to distinguish between alternative underlying preferences and technologies. The concept of *microeconomic dissonance* refers to the fact that the underlying microeconomic differences become important when optimal monetary policy is analyzed in a nonlinear setting. The relevance of these concepts is established by analysis of optimal steady-state inflation and optimal policy in the stochastic economy using a small-scale New Keynesian model. Microeconomic and financial datasets are promising tools with which to overcome the equivalence problem.

1 Introduction

A significant dilemma for monetary policy advice and model selection arises from the coexistence of two phenomena: *macroeconometric equivalence* and *microeconomic dissonance*. The term *macroeconometric equivalence* describes a situation where approaches based on estimating first-order approximations of model equilibrium conditions on aggregate time series data do not reveal definitively the economy's underlying preference/technology structure. For some positive-economics applications—for example, determining the degree of forward-looking behavior in pricing or spending decisions—the equivalence need not pose major problems. The first-order properties of the model may be sufficient for answering many positive-economics issues, and no harm may arise from taking two models to be interchangeable if their first-order dynamics are isomorphic. Normative applications, however, raise more concern. Results regarding optimal monetary policy do depend on the objective functions and production functions in the underlying nonlinear economy. Models that are equivalent when loglinearized therefore need *not* be equivalent in what they imply for optimal monetary policy—i.e., for the optimal steady-state inflation rate and the characteristics of efficient policy in the stochastic economy. *Microeconomic dissonance* refers to case where two models whose structural equations are first-order equivalent yield different optimal monetary policies. This study considers several strategies for resolving the dilemma posed by the equivalence/dissonance dichotomy, and offers conclusions about which strategy should be followed.

The macroeconometric equivalence/microeconomic dissonance issue has received little attention in the modern monetary policy literature. While King and Wolman (1996), for example, provide a detailed analysis of the sensitivity of the optimal inflation rate to different parameter assumptions in their dynamic general equilibrium model, they do not consider the sensitivity of the optimal-policy analysis to assuming a different (but first-order equivalent) price-setting specification. This is despite the fact that economists have been well aware of the tendency for macroeconometric equivalence to arise between models that are far apart in their basic assumptions about private sector behavior. The notion that different rational expectations models may deliver the same linearized dynamics is of long standing: Sargent (1976) noted that two different struc-

tural models can deliver the same reduced form even when only one model imposes the natural rate restriction, while Taylor (1997), among others, noted that certain sticky-price and Lucas-style imperfect-information models deliver similar aggregate supply relationships.

Likewise, instances of microeconomic dissonance, while less prevalent and less appreciated, underpinned such early contributions to the New Keynesian literature as Caplin and Spulber (1987) and Ball and Romer (1990). Caplin and Spulber produced a case where price stickiness at the micro level magnifies the welfare costs of inflation but produces identical monetary-neutrality results to those of a flexible-price model. Ball and Romer provided an example of two preference specifications which, while equivalent in their implications for the degree of aggregate output volatility, lead to substantially different welfare costs from that volatility.

But the taking-off of New Keynesian models in the last fifteen years has not been associated with a major reaffirmation of the dissonance warning. The modern New Keynesian literature has typically proceeded under the assumption that observationally equivalent models do deliver similar policy prescriptions. Our conjecture is that this conclusion has been prevalent until now because it followed from the study of the best-known instance of macroeconometric equivalence in the New Keynesian literature: that of the Rotemberg (1982) and Calvo (1983) price-setting specifications.[1] Rotemberg and Calvo price schemes have very different microfoundations: in the Rotemberg setup, all firms vary prices each period as a continuous function of marginal cost; in the Calvo setup, a fraction of firms is selected randomly to adjust prices each period, the remaining fraction being prohibited to adjust, so price adjustment at the individual-firm level is very abrupt rather than continuous. Yet the two price adjustment specifications deliver equivalent aggregate Phillips curves (Rotemberg, 1987; Roberts, 1995). There is therefore macroeconometric equivalence and, given the different model underpinnings, the potential for microeconomic dissonance. But the optimal policies implied by the Calvo and Rotemberg alternatives are not, in fact, very different quantitatively.[2] This influential equivalence result is therefore probably responsible for the wide-

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[1]The Calvo specification is the most prevalent price-adjustment setup in the New Keynesian literature. Calvo himself noted that his price-setting scheme was "a close relative of the staggered contracts model... of Taylor (1979, 1980)."

[2]In fact, Lombardo and Vestin (2007) and Nistico (2007) both demonstrate that second-order welfare functions (approximated near an efficient steady state) are identical across Calvo and Rotemberg settings. The quantita-

spread impression that microeconomic dissonance is not an important phenomenon in modern New Keynesian modeling.

The objects of this study are to dispel this impression and offer strategies to resolve the resulting dilemma for policymaking and modeling. Our examples of equivalence do not simply draw on the existing literature; nevertheless, and unlike the aforementioned early New Keynesian contributions, the focus is on the standard, modern New Keynesian model consisting of the forward-looking IS and Phillips curves. This focus establishes that important equivalence and dissonance results emerge even with this widely used benchmark model. This model is, in addition, essentially a restricted and stripped-down version of the dynamic stochastic general equilibrium (DSGE) models estimated in such studies as Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003, 2005) and Levin, Onatski, Williams, and Williams (2005). As these medium-scale models explain actual U.S. and euro area data well, it is realistic to say that the New Keynesian literature is converging on a DSGE model whose first-order approximation is a good description of macro-economic data. It has accordingly become imperative to evaluate the differences in policy advice implied by models that are equivalent in their first-order properties, and also to determine the best strategy for discriminating between alternative microeconomic underpinnings of such models.

And it deserves emphasis that policy advice cannot typically be determined by the first-order dynamics of these models. True, in some positive-economics applications—for example, estimation of Phillips or IS curves, or estimation of the monetary policy rule over a sample period in which policy has not attempted to maximize household utility—only the loglinear approximation of the model may be needed. But, as noted above, the same is not true for normative applications. Increasingly, it has become standard to draw out the policy implications of a microfounded model by determining optimal monetary policy in that model. Even when studying simple monetary policy rules, it is not unusual to rank these rules according to the extent that they maximize household utility. This involves evaluation of the nonlinear utility function, or of a second- or higher-order approximation of utility. Either way, higher-order properties of the model become relevant, and

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tive results presented by Lombardo and Vestin further suggest that, even when the steady state is inefficient, the characteristics of the Ramsey-optimal equilibrium are very similar across the two pricing specifications.

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one cannot draw policy implications immediately from the loglinear representations of the model, which do not adequately identify these nonlinear elements.

The equivalence of two underpinnings of the New Keynesian Phillips curve is established below. Each version of the Phillips curve arises from a particular type of strategic complementarity: firm-specific inputs in one case, and a kinked demand structure in the other. Numerical results for optimal steady-state inflation are provided that demonstrate the contrasting policy advice implied by each specification. Analysis of the aggregate demand side then establishes that the standard optimizing IS equation is consistent both with orthodox expected-utility preferences and with Epstein-Zin (1989) preferences, and show that the different rationalizations for the IS curve are associated with distinct dynamic properties of optimal monetary policy. The discussion then turns to an exploration of alternative strategies for dealing with the equivalence/dissonance combination.

A potential remedy for the equivalence/dissonance problem may be found in econometric procedures capable of estimating versions of the model based on higher-order approximations (as in Fernández-Villaverde and Rubio-Ramírez, 2007), or in considering alternative macroeconomic data. But our conclusion is that a more promising alternative is to deploy datasets not consisting purely of macroeconomic time series. Microeconomic datasets may be very revealing about economic structure. Studies by Bils and Klenow (2004), Angeloni *et al* (2006), and Nakamura and Steinsson (2008) emphasize the value of micro-level information in understanding inflation dynamics. The value of these extra datasets in resolving the equivalence/dissonance dilemma does not arise inherently from the fact that they are micro data, but that they constitute a *different type* of data from standard macro series, and so help pinpoint parameters not identifiable using macro data. Resolution of macroeconometric equivalence and microeconomic dissonance need not always involve considering micro data, but will typically involve looking at data beyond macroeconomic time series. Besides micro data, financial data are promising candidates in this connection. Asset price analysis could prove to be similarly revealing about aggregate demand behavior. Taken together, these alternative datasets provide a discipline on the specification of models intended for

monetary policy analysis that macroeconomic data often fail to provide, and in so doing help draw out more accurate policy implications of a macroeconomic model.

The analysis proceeds as follows. Section 2 describes a prototype New Keynesian model, describing the nonlinear environment, deriving the implied equilibrium conditions, and setting out the central loglinearized equations. Section 3 considers two real rigidities and their implications for the slope of the Phillips curve and optimal policy. Section 4 considers strategies for resolving the equivalence/dissonance dilemma. Section 5 turns the analysis toward the IS equation, focusing on the IS slope parameter, and detailing the different welfare implications of risk-sensitive preferences compared to the standard expected-utility case. Section 6 discusses the deployment of financial data to bring out differences between macroeconometrically equivalent IS curves. Section 7 provides concluding remarks.

2 A prototypical New Keynesian model

Below is an outline of a baseline New Keynesian model, which serves as a prototype to which the subsequent analysis adds variations.

A representative household seeks to maximize intertemporal utility $E_0 \sum_{t=0}^{\infty} \beta^t U_t$, where $U_t = \frac{C_t^{1-\sigma}-1}{1-\sigma} - \chi_0 \frac{N_t^{1+\chi}}{1+\chi} + \nu_0 \frac{(\frac{M_t}{P_t})^{1-\nu}}{1-\nu}$, C_t is an aggregate of the different goods consumed, N_t denotes hours worked, and $\frac{M_t}{P_t}$ is the household's stock of real money balances. All parameters are positive, with $\beta \in (0,1)$ the discount factor. Money is present in the utility function so that, as in Khan, King and Wolman (2003) and Schmitt-Grohé and Uribe (2004), monetary frictions can be a factor entering into the determination of optimal steady-state inflation.

Each member of a continuum of firms specializes in producing a particular intermediate good. These goods are then used as components in the generation of a single, final consumption good. The production function for an intermediate-good-producing firm j is $Y_t(j) = A_t K_t(j)^{\alpha} N_t(j)^{1-\alpha}$ where A_t is an exogenous productivity shock, $K_t(j)$ and $N_t(j)$ are quantities of capital and labor services hired by firm j, and $\alpha \in [0,1)$. Price adjustment for intermediate goods is subject to the Calvo (1983) apparatus. So each period a fraction $1-\xi$ of firms receives clearance

to reset prices, while a fraction ξ must hold prices at preexisting levels.

Perfect competition describes the labor market. Capital and labor are mobile across firms, so all intermediate firms confront the same real marginal cost, $MC_t = w_t N_t / (1 - \alpha) Y_t$. Here $Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} \, dj \right)^{\frac{\epsilon}{\epsilon-1}}$ is output compiled from intermediate goods by the final-goods producer, and $\epsilon > 1$. (An alternative aggregation technology is considered in Section 3.) The aggregate capital stock is fixed, implying a market-clearing condition $C_t = Y_t$. An intermediate-good producer faces a demand function from the final producer of the form $\widetilde{Y}_t(j) = \widetilde{P}_t(j)^{-\epsilon}$, where $\widetilde{Y}_t(j) = \frac{Y_t(j)}{Y_t}$, $\widetilde{P}_t(j) = \frac{P_t(j)}{P_t}$, and the aggregate price index is given by $P_t = \left(\int_0^1 P_t(j)^{1-\epsilon} \, dj \right)^{\frac{1}{1-\epsilon}}$.

As in Khan, King, and Wolman (2003), the relative price dispersion that results from Calvo staggering can be interpreted as an inefficiency that, by misallocating resources across the intermediate goods sector compared to the flexible-price scenario, depresses the equilibrium level of final aggregate output. Letting $N_t = \int_0^1 N_t(j) dj$ denote aggregate labor and normalizing aggregate capital at $\overline{K} = 1$, the same misallocation index (Δ_t) as in Khan, King, and Wolman's model is relevant, being related to output as $Y_t = (\frac{A_t}{\Delta_t}) N_t^{1-\alpha}$, while Calvo contracts imply that this distortion follows a first-order difference equation,

$$\Delta_t = (1 - \xi)(\tilde{P}_t^*)^{-\epsilon} + \xi \Pi_t^\epsilon \Delta_{t-1}. \tag{1}$$

where $\tilde{P}_t^*$ is an index of the relative reset price. As all price change in a particular period comes from firms acting on a reset signal, there is a relation between the economy's gross inflation rate and the reset price index:

$$\Pi_t = \left[\frac{1 - (1 - \xi)(\tilde{P}_t^*)^{1-\epsilon}}{\xi} \right]^{\frac{1}{\epsilon-1}}. \tag{2}$$

A loglinear approximation of the preceding model yields the optimizing IS equation,

$$y_t = E_t y_{t+1} - \sigma^{-1} \left[r_t - E_t \pi_{t+1} \right], \tag{3}$$

and the New Keynesian Phillips curve,[3]

$$\pi_t = \beta E_t \pi_{t+1} + \kappa mc_t. \tag{4}$$

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[3] Hornstein and Wolman (2007) consider the pricing dynamics implied by the fully nonlinear version of this prototype model (i.e., without reliance on the loglinear approximation).

Here, y_t is the log-deviation of output from its steady-state growth path, mc_t is the log-deviation of real marginal cost from its steady-state value, and π_t and r_t respectively denote deviations of quarterly inflation and the short-term nominal interest rate from their steady-state values.

The next step is to consider extensions of this prototype model. Each extension involves a change in economic structure that alters the form of optimal monetary policy. But in no case does the extension, despite its critical impact on welfare implications of the model, change the IS and Phillips curves from their loglinearized forms given above—the essence of the macroeconometric equivalence problem.

3   Real rigidities and the slope of the Phillips curve

Let us now consider two types of real rigidity which lower firms' inclination to increase prices in the face of a surge in nominal aggregate demand (see e.g. Woodford, 2003, Ch. 3). The two real rigidities are isomorphic in their implications for loglinear dynamics, but differ in their second-order repercussions and therefore are associated with different welfare results.

3.1   Non-constant elasticity of demand *vs.* factor specificity

Kimball (1995) reformulated the venerable kinked, or variable-elasticity, specification of goods demand and combined it with Calvo price setting. This demand structure is the first real rigidity contemplated here.

Dotsey and King's (2005) proposal for aggregating across the intermediate goods $Y_t(j)$ is followed here. Continuing to let $\widetilde{Y}_t(j) = \frac{Y_t(j)}{Y_t}$ denote the share of each intermediate in final output, the Dotsey-King aggregator is:

$$G(\widetilde{Y}) = \frac{\phi}{1+\psi}\left[(1+\psi)\widetilde{Y} - \psi\right]^{\frac{1}{\phi}} - \left[\frac{\phi}{1+\psi} - 1\right], \tag{5}$$

where $\phi = (\epsilon(1+\psi))/(\epsilon(1+\psi)-1)$, and $\epsilon > 1$ is the standard Dixit-Stiglitz (1977) good-j price elasticity of demand. The profit-maximizing intermediate-good mix is selected, and the aggregator satisfies $\int_0^1 G(\widetilde{Y}_t(j))\, dj = 1$.

The parameter ψ governs curvature of demand for an intermediate firm's product. It yields the familiar Dixit-Stiglitz constant-elasticity demand function for $\psi = 0$. The less standard case of $\psi < 0$ is now considered. This is the setting of quasi-kinked demand. Demand for the firm's brand is progressively more price-elastic until it reaches a region of virtual satiation; a reduction in relative price in this region barely stimulates demand. A price *increase*, on the other hand, runs the risk of pushing firms away from the moderate-elasticity region into a further region where demand virtually collapses: see Figure 1. Buyers' optimal purchasing pattern among the available goods means that the relative demand for product j can be described as:

$$\widetilde{Y}_t(j) = \frac{1}{1+\psi} \left[\widetilde{P}_t(j)^{-\epsilon(1+\psi)} \lambda_t^{\epsilon(1+\psi)} + \psi \right], \tag{6}$$

where again $\widetilde{P}_t(j)$ is intermediate good j's relative price. The Lagrange multiplier appearing in equation (6) is defined as $\lambda_t = \left(\int_0^1 \widetilde{P}_t(j)^{1-\epsilon(1+\psi)} \, dj \right)^{\frac{1}{1-\epsilon(1+\psi)}}$, and so collapses to unity in the Dixit-Stiglitz case of $\psi = 0$. The more general case of $\psi < 0$ implies that good j has a fluctuating demand elasticity, denoted $\eta(\widetilde{Y}_j)$ and given by the formula:

$$\eta(\widetilde{Y}_j) = \epsilon \left(1 + \psi - \psi \widetilde{Y}_j^{-1} \right), \tag{7}$$

so that the elasticity varies inversely with the proportion of the final producer's total demand that is directed at firm j. An intermediate producer's desired markup is $\mu(\widetilde{Y}_j) \equiv \frac{\eta(\widetilde{Y}_j)}{\eta(\widetilde{Y}_j)-1}$; this includes the familiar case $\mu(1) = \mu = \frac{\epsilon}{\epsilon-1}$ in the instance of $\psi = 0$, but is a function of relative demand when ψ is nonzero.

Table 1 presents optimal price-setting conditions for firms in this environment. The table juxtaposes the Dixit-Stiglitz and kinked-demand cases as represented by the implied desired relative price $\widetilde{P}_t^*$ and its components Z_{1t}, Z_{2t}, and Z_{3t}.[4] The price $\widetilde{P}_t^*$ selected by firms when allowed to adjust, reflects the need to take into account anticipated fluctuations in the elasticity of demand (i.e., the λ_t variable) over the period in which the price is expected to be fixed.

As detailed in many studies, this model implies a loglinear Phillips curve,

$$\pi_t = \beta E_t \pi_{t+1} + \gamma \kappa_p mc_t. \tag{8}$$

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[4]See Levin, López-Salido, and Yun (2007a) for a derivation of the law of motion for the relative-price-dispersion metric in this model environment.

Table 1: Price-Setting Behavior

Prototype Model	Quasi-Kinked Demand
$\widetilde{P}_t^* = \frac{\epsilon}{\epsilon-1}\frac{Z_{2t}}{Z_{1t}}$	$\widetilde{P}_t^* = \phi\frac{Z_{2t}}{Z_{1t}} + \left(\frac{\psi\phi}{\epsilon(1+\psi)}\right)\frac{Z_{3t}}{Z_{1t}}\left(\widetilde{P}_t^*\right)^{1+\epsilon(1+\psi)}$
$Z_{1t} = E_t\{\ \beta\xi\Pi_{t+1}^{\epsilon-1}\ Z_{1t+1}\ \} + C_t\Phi_t$	$Z_{1t} = E_t\{\ \beta\xi\Pi_{t+1}^{\epsilon(1+\psi)-1}\ Z_{1t+1}\ \} + C_t\Phi_t\lambda_t^{\epsilon(1+\psi)}$
$Z_{2t} = E_t\{\ \beta\xi\Pi_{t+1}^{\epsilon}\ Z_{2t+1}\ \} + C_t\Phi_t MC_t$	$Z_{2t} = E_t\{\ \beta\xi\Pi_{t+1}^{\epsilon(1+\psi)}\ Z_{2t+1}\ \} + C_t\Phi_t\lambda_t^{\epsilon(1+\psi)}MC_t$
$\Phi_t = U_{C,t} = C_t^{-\sigma}$	$Z_{3t} = E_t\{\ \beta\xi\Pi_{t+1}^{-1}\ Z_{3t+1}\ \} + C_t\Phi_t$

This is a standard New Keynesian Phillips curve (with marginal cost the driving process) other than the factorization of the Phillips curve slope into two components. One component governs nominal rigidity; the other, real rigidity (with the "no real rigidity" case corresponding to $\gamma = 1$). Where previously the Phillips curve slope κ arose simply from nominal rigidity, now the slope is a composite of the nominal-rigidity parameter κ_p–which is a function of the frequency of price adjustment ξ and the discount factor β: $\kappa_p = \frac{(1-\xi)(1-\xi\beta)}{\xi}$—and the real-rigidity parameter $\gamma = \frac{1}{1-\mu\psi}$, where μ is the prototype-model steady-state markup defined above. The demand-curve kink condition $\psi < 0$ implies that γ is below unity, approaching zero as ψ becomes more negative. It follows that kinked demand for intermediate-firm output dampens the reaction of inflation to fluctuations in marginal cost, putting this model feature in the category of strategic complementarities discussed in Woodford (2003).

Let us now revert to the assumption of a Dixit-Stiglitz demand structure ($\psi = 0$) in order to consider a different source of real rigidity. In our prototype model, the physical capital stock was constant across periods in aggregate, but not for any individual firm, which could access extra capital services via a rental market. The environment is now changed to one where a portion of the intermediate firm's capital stock is of a firm-specific character and so cannot be replenished by going to the rental market,[5] and likewise, let us assume some firm-specific labor (which is to say, firm-specific human capital). In these circumstances real marginal cost for the generation of

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[5] See Sbordone (2002), Woodford (2003, 2005), and Altig, Christiano, Eichenbaum, and Linde (2005) for further discussion of firm-specific capital.

good-j output can diverge from the economy's average real marginal cost: the ratio $\widetilde{MC}_t(j) = MC_t(j)/MC_t$ can depart from 1.0. Firm j's production function is now

$$Y_t(j) = A_t \ \overline{K}^{\alpha_{fk}} \ K_t(j)^{\alpha_{vk}} \ \overline{N}^{\alpha_{fl}} \ N_t(j)^{\alpha_{vl}}. \tag{9}$$

Here $\alpha_{fk} > 0$, $\alpha_{vk} > 0$, $\alpha_{fl} > 0$, $\alpha_{vl} > 0$, and $\alpha_{fk} + \alpha_{vk} + \alpha_{fl} + \alpha_{vl} = 1$. Overbars denote immobile production factors. Accordingly $\alpha_f = \alpha_{fl} + \alpha_{fk}$ is the fraction of factors (capital and labor inputs) special to firm j. Firm-specific inputs mean that payments to factor services, and therefore marginal cost, can differ across firms. Deviations of a firm's marginal cost from the aggregate in turn reflect differences in any given firm's output from the output level prevailing on average across the economy: that is, $\widetilde{MC}_t(j) = \widetilde{Y}_t(j)^{\frac{1-\alpha_f}{\alpha_f}}$. Relatively high production levels reduce a firm's marginal cost compared to the economy-wide average. A firm is deterred from raising its price by the fact that the induced decrease in its demand will rebound on it by reducing its equilibrium output and raising its marginal cost.

As shown in Levin, López-Salido, and Yun (2007a), the profit-maximization condition in the case of firm-specific factors (which supersedes the prototype-model expression in Table 1) is:

$$\left(\widetilde{P}_t^*\right)^{1+\epsilon \frac{\alpha_f}{1-\alpha_f}} = \frac{\epsilon}{\epsilon - 1} \frac{Z_{2t}}{Z_{1t}}. \tag{10}$$

The expressions for variables Z_{1t} and Z_{2t} revert to the prototype case because our analysis has resumed use of the Dixit-Stiglitz standard (i.e., $\psi = 0$). But firm-specific factors introduce the power $1 + \epsilon \frac{\alpha_f}{1-\alpha_f}$ into the pricing expression. The optimal price charged by adjusting firms therefore depends in a concave manner on the expected stream of markups. This concavity is a manifestation of strategic complementarity. With this concavity, and assuming positive inflation, firms setting prices at time t have incentives to subdue their actions on prices compared to the baseline, no-real-rigidity case.

As was the case with the kinked-demand modification, the introduction of fixed factors means a New Keynesian Phillips curve of the form (8). The expression for the Calvo-related coefficient κ_p is unchanged from that given previously, but the real-rigidity coefficient becomes $\gamma = \frac{1}{1+\epsilon \frac{\alpha_f}{1-\alpha_f}}$. This expression illustrates the strategic-complementarity character of fixed inputs.

The higher the share of fixed inputs in production (α_f), the more inflation's response to marginal cost is suppressed.

3.2 Implications for the steady-state inflation rate

The foregoing results are now illustrated quantitatively. The discount factor used is $\beta = 0.993$, there are log preferences over consumption ($\sigma = 1$), a unit Frisch labor elasticity ($1/\chi = 1$), and a production function parameter of $\alpha = 0.33$. The steady-state markup is set to 16%, corresponding to $\epsilon = 7$. The money demand parameter value used is $\nu = 11.4$, so as to generate an interest elasticity of money demand in the same ballpark as that in Khan, King, and Wolman (2003).

Our criteria are to generate a Phillips curve slope ($\kappa_p \gamma$) of 0.025, in line with time series estimates of the elasticity of inflation to current real marginal cost. κ_p is fixed so as to keep the implied average interval between a firm's price adjustments to about three quarters, in line with microeconomic evidence (i.e., $\xi = 0.6$, as before). These choices imply $\gamma \cong 0.1$. The model-specific parameter is fixed at a value that ensures this γ. So $\psi = -8$ in the case of quasi-kinked demand; and $\alpha_f = 0.58$ in the case of firm-specific inputs.

Figure 2 plots the relationship between the parameters—i.e., ψ and α_f—that govern each strategic complementarity, and the corresponding optimal inflation rate. These results refer to experiments where only a single strategic complementarity is present each time, so a zero value of the parameter corresponds to the no-real-rigidity case. With no real rigidity present, the Friedman (1969) rule is close to optimal and 2.5% deflation is the optimal steady-state rate. But, irrespective of which strategic complementarity is considered, introducing the complementarity shifts the balance in favor of zero inflation, the more so the greater the economic importance of the real rigidity.

3.3 Optimal policy in the stochastic economy

The second-order approximations of household welfare for the two types of strategic complementarity analyzed above are derived in Levin, López-Salido, and Yun (2007a).[6] In both cases, the

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[6] To concentrate on the second-order approximation, it is assumed that subsidies have moved the steady-state level of output to its efficient level. It is also now assumed that the economy has reached the cashless limit.

assumption of wage flexibility means that real marginal cost has a loglinear relationship with the output gap: $mc_t = \lambda_x x_t$. The coefficient λ_x is also the weight on output-gap fluctuations in the social welfare function. The constraint faced by an optimizing policymaker can accordingly be written as an output-gap New Keynesian Phillips curve, $\pi_t = \beta E_t \pi_{t+1} + (\lambda_x \kappa_p \gamma) x_t$, which is identical across the two types of strategic complementarity (other than the definition of potential output underlying the gap x_t). Furthermore, in both cases the policymaker problem may be written as constrained minimization of $\sum_{t=0}^{\infty} \beta^t E_0 [\lambda_\pi \frac{\pi_t^2}{2} + \lambda_x \frac{x_t^2}{2}]$, and so in general terms the period loss function coincides with that derived for New Keynesian models by Rotemberg and Woodford (1997) and Woodford (2003).

The policymaker's problem is nevertheless distinct across the two cases because the expression for the inflation-variability weight, λ_π, depends crucially on which of the two mechanisms is the source of strategic complementarity. In the kinked-demand setting, the weight is $\lambda_\pi = \epsilon/\kappa_p$, while this instead becomes $\lambda_\pi = \epsilon/(\kappa_p \gamma)$ in the case of fixed factor inputs. With kinked demand, therefore, inflation optimally exhibits a more powerful response to the movements in the output gap: the relative weight on inflation variability being lower in the welfare function, more inflation variability is tolerated to flatten the output gap path. Inflation variations are more tolerable in the kinked-demand-curve case because the approximation of the stochastic economy takes place in a region where relative-demand reactions (and so equilibrium allocations of resources) are quite price-insensitive, so the relative-price fluctuations associated with inflation variations become less costly.

3.4 The cost of inflation in the presence of strategic complementarities

Let us consider the effect that the type of strategic complementarity has on estimates of the time series behavior of relative price distortions. As noted above, the framework of Dixit-Stiglitz bundling and Calvo pricing leads to a relation between the relative price distortion metric and inflation of the form:

$$\Delta_t = (1 - \xi)(\frac{1 - \xi \Pi_t^{\epsilon-1}}{1 - \xi})^{\frac{\epsilon}{\epsilon-1}} + \xi \Pi_t^\epsilon \Delta_{t-1}. \tag{11}$$

This expression is used to construct time series for the distortions $\{\Delta_t\}_{t=0}^T$ given an initial

value Δ_{-1} and observed aggregate U.S. inflation $\{\pi_t\}_{t=0}^{T}$.[7] The initial condition for the distortion takes the steady-state value: $\Delta_{-1} = \Delta = \frac{1-\xi}{1-\xi(1+\pi)^\epsilon}(\frac{1-\xi(1+\pi)^{\epsilon-1}}{1-\xi})^{\frac{\epsilon}{\epsilon-1}}$. This steady-state value is obtained using the average inflation rate over our pre-sample observations, 1947:1-1959:4. As before, $\xi = 0.6$ and $\epsilon = 7$ are assumed.

Figure 3 depicts the implied relative price distortion index, for each of the two settings of strategic complementarity over the quarterly sample 1960:1-2005:3. Relative price distortion rises in the early 1970s to peak in the middle of the decade. Visually there are similarities with Fischer's (1982, Fig. 1a) measure of relative price variability, the main difference being that for Fischer the early 1980s peak slightly exceeds the mid-1970s peak. Fischer's series ends in the early 1980s; our longer series show sharp declines in relative price variability after 1982 and low values in the 1990s.

The two distortion measures generated by the alternative real-rigidity models are highly correlated, but the scale of their variations are different. This is a mirror image of the fact that the specification of real rigidity impacts significantly on the welfare implications of price dispersion. In the model variant with quasi-kinked demand, the period 1965-81 of turbulent and high inflation generates quantitatively modest levels of inefficiency via relative price dispersion. By contrast, the case of firm-specific factors yields much higher welfare losses: the relative price distortions reduce the level of aggregate output by 10 percent or more. Either way, the measure of relative price distortion depends principally on the inflation level, taking a steady-state value of zero when long-run average inflation is itself zero.

4 Resolving macroeconometric equivalence using economic data

At this point it is appropriate to consider strategies that might overcome the macroeconometric equivalence established above, and in so doing determine the underlying economic structure. The first option considered is that of more intensive use of macroeconomic information, followed by a discussion of the option of deploying microeconomic data.

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[7]In our loglinear derivations, π_t denotes the log-difference in the price level. Our empirical generation of the relative price distortion index, however, defines π_t as the percentage change in the price level: $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$.

4.1 More macroeconomic information

Macroeconomic information that might supplement a standard analysis includes estimates of more accurate approximations of the macroeconomic model (that is, estimates that use a higher-order approximation); and additional macroeconomic series. Each of these options is considered below.

As noted in the introduction, econometric techniques are available for breaking macro-econometric equivalence by estimating systems that approximate the general equilibrium model to a higher order than the loglinear baseline. But it is doubtful that such methods can in practice be relied upon to break macroeconometric equivalence.

The equilibrium solution of a loglinearized DSGE model can be cast as a restricted VAR system. Therefore, the contention that estimation of nonlinear models resolves macroeconometric equivalence problems amounts to the following claims: that the restrictions on VARs needed to obtain DSGE models are generally rejected in practice (so that loglinearized DSGE models are not viable empirically); and/or that nonlinear empirical models significantly outperform unrestricted VARs in terms of fit (so that unrestricted VARs are too weak a benchmark for structural empirical models). Neither of these claims seems to have support from the balance of the literature. The modeling stage seems to have been reached where medium-scale loglinearized DSGE models do not seem to be rejected as restrictions on VARs. And we are not aware of compelling evidence that models that are nonlinear (in variables) outperform VARs for the modeling of macroeconomic series; Sims (1998, p. 939), for example, argues that the "best evidence" is that nonlinearity is "of modest quantitative significance."

Morley and Piger (2006) argue that nonlinear models are needed for reproducing business cycle regularities. On close inspection, however, Morley and Piger's findings do not repudiate the macroeconomic literature's concentration on loglinearized models. For one thing, Morley and Piger confirm that linear models are sufficient for capturing the extent of observed output peaks and troughs, thus suggesting that the local approximations implied by first-order representations are not empirically inadequate. Furthermore, the type of nonlinearity Morley and Piger emphasize as empirically important is the "plucking model" feature that rapid expansions follow deep recessions

but not shallow recessions. This, however, is a type of regularity that is unlikely to be invariant to the specification of the monetary policy rule, and so not a regularity that one would want to impose on the structure of a general equilibrium model. It is a regularity that may call for a nonlinear model if one is modeling real GDP as a univariate process (as Morley and Piger do), but not necessarily if one is modeling in a general equilibrium framework.

It might be argued that the existing literature understates the degree of nonlinearity in the data because so much of it (both VAR and DSGE) is conditioned on the assumption of a constant policy regime over the sample period (with perhaps one break allowed in 1979-80), and, with that assumption, a constant steady-state inflation rate. According to this argument, nonlinear elements of the model structure might be recovered by using a better, more flexible specification of the Federal Reserve's policy rule. Some recent work, while still using loglinearized structural models, does allow for more changes in monetary policy regime by allowing for a shifting Federal Reserve inflation target: for example, Ireland (2007), Smets and Wouters (2005), and Cogley and Sbordone (2008). If nonlinearity in model structure impacted heavily on macroeconomic behavior, then it is plausible that estimates of the IS and Phillips curve slopes in the loglinearized model would be highly sensitive to respecification of the policy rule, since the loglinear approximation in that case would be very fragile. But to our knowledge none of this work establishes that IS and Phillips curve slope estimates are dramatically changed by allowing for a policy regime change; indeed, Ireland (2007) fixes the IS and Phillips curve slopes at values obtained in preexisting studies. So allowing for this form of nonlinearity in the policy rule does not seem to offer an obvious path to determining the nature of the nonlinearity in private sector structural behavior.

In principle, any variable that depends on expected future inflation or expected future output is informative about the true structure driving inflation and output. The expectation of future output depends on the structural parameters in the IS equation, and the expectation of future inflation depends on the structural parameters in the Phillips curve. But expanding the macro dataset to include forward-looking indicators (e.g., by including monetary, credit, or wealth aggregates), and adding the corresponding equilibrium conditions pertaining to these variables,

will not resolve the equivalence problem. The reason is that the macroeconometric equivalence means that linear projections of inflation are the same irrespective of model specification—so (e.g.) the sequence of expected inflation rates $\{E_t\pi_{t+1}, E_t\pi_{t+2}, \ldots\}$ is identical across the fixed-input and kinked-demand model variants of our model. Therefore, obtaining more precise estimates of those projections is uninformative for the task of distinguishing between the alternative model specifications.

It is therefore not clear that exploitation of information from further macroeconomic variables will resolve macroeconometric equivalence. This leads to our interest in alternative datasets. For Phillips curve analysis, the key alternative to macroeconomic time series data consists of micro-level information.

4.2   Microeconomic data

Microeconomic datasets have the potential to resolve Phillips curve equivalence, as they reveal features of the firm-level problem that are lost in aggregation. For our purposes, the most clear-cut way to break the Phillips curve equivalence is to establish whether firms face a kinked demand curve for their product. Kinked demand is associated with only one of the rationalizations of the New Keynesian Phillips curve, and so evidence on demand curvature breaks the equivalence. Such curvature is governed by a parameter (the individual-good demand elasticity) that cannot be recovered from the aggregate Phillips curve, but on which relevant microeconometric evidence exists. Klenow and Willis (2006) come out against Kimball (1995)-type kinked demand curves using microeconometric tests.[8] But a more optimistic conclusion about the realism of kinked demand is made by Dossche, Heylen, and den Poel (2006), again using micro data (in their case, euro-area scanner data on both prices and quantities). Dossche, Heylen and den Poel find, in line with kinked-demand theory, that price increases trigger proportionately greater demand reactions than do reductions in price. They caution against curvature of demand of the magnitude used by Kimball (1995), but see their results as supportive of moderately kinked behavior in goods demand. The

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[8]Traditional kinked-demand curve analysis had been subject to an earlier critique using industry data in Stigler (1947).

case study by Levitt (2006), while covering only one firm, is also supportive of the kinked-demand view that there is a price-inelastic band on the consumer demand curve and that price setting in practice is such that equilibrium quantities occur in that band. Results such as these suggest tentatively that kinked demand should be preferred to fixed inputs in deriving the Phillips curve, in order to tie macroeconomic model specification more closely to microeconomic evidence.

At the same time, though the preceding discussion has cast the issue in terms of the choice between two alternative specifications of real rigidity, one should always be aware that there is evidence against both specifications. Still further real rigidities might be contemplated. Furthermore, one could argue that the sensitivity of welfare to these specification choices, as depicted in Figures 2 and 3, is too great for either specification to be credible. Calvo pricing, while a reasonable approximation in describing observed inflation behavior, might be too major an abstraction to use in welfare and counterfactual analysis. The extreme costs of inflation that result from its interaction with the firm-specific-factors environment may be a reflection of stretching the Calvo framework too far. In that light, an important complement to standard New Keynesian modeling is the research agenda that applies state-dependent pricing to monetary policy models (as in Dotsey, King, and Wolman, 1999) and evaluates Calvo pricing in terms of its ability to approximate state dependence (see e.g. Dotsey and King, 2005; Basu, 2005; Gertler and Leahy, 2006; Caballero and Engel, 2007; and Woodford, 2008). Nominal rigidities might also receive stronger foundations from behavioral theories of firm and consumer behavior (see Rotemberg, 2007). But the bottom line regarding microeconomic data remains: datasets containing information on individual firms can help in discriminating between specifications that appear equivalent when using conventional macroeconomic approaches. Such microeconomic datasets serve as an important discipline on monetary policy analysis, since they can reject proposed explanations for observed time series behavior that could not be ruled out with macroeconometric tests.

5   Household preferences and the slope of the IS curve

The Euler condition encapsulating household aggregate consumption choice is the basis for the IS equation used in New Keynesian analysis. But, as Sargent (2007, p. 301) observes, "A long list of empirical failures called puzzles come from applying... that Euler equation. Until we succeed in getting a consumption-based asset pricing model that works well, the New Keynesian IS curve is built on sand." That is, the nonlinear model typically used to derive the IS function fails to account for routine financial market facts. Standard household preference specifications (hereafter called "expected utility") cannot explain the substantial premium priced into risky instruments, and are hard to reconcile with the variability of long-term asset returns.

Recognizing the weaknesses of the expected-utility specification, the analysis here examines the implications for IS curve specification and optimal monetary policy of Epstein-Zin (1989) preferences. A further instance of macroeconometric equivalence and microeconomic dissonance then emerges. To our knowledge, the analysis here amounts to the first attempt to integrate the Epstein-Zin preference structure into an otherwise standard sticky-price New Keynesian setup.

The attraction of Epstein-Zin preferences is that they break the simple connection between the coefficient of relative risk aversion and the intertemporal elasticity of substitution in consumption. Epstein-Zin preferences accordingly might account for the coexistence of key securities market features (in particular, low real rates on risk-free securities) and key equity market features (notably the equity premium puzzle), which less flexible preference specifications may find irreconcilable (see e.g. Tallarini, 2000; Brevik, 2005).

5.1   Expected utility *vs.* Epstein-Zin preferences

Compared to the prototype model in Section 2, the model now has two modifications. First, the production function is specialized to be linear in labor. Second, preferences are extended to take the Epstein-Zin form. The implications of the extended preference specification for the household and firm problems are outlined below.

Household's preferences are defined in a recursive way as:

$$U_t = V_t + \frac{\beta}{\sigma} \log(E_t[\exp(\sigma U_{t+1})]), V_t = \log C_t + \varphi_0 \log(1 - N_t) + \nu_0 \log(\frac{M_t}{P_t}), \qquad (12)$$

where $\sigma = \frac{(1-\beta)(1-\varphi)}{1+\varphi_0}$. This specification corresponds to Tallarini's (2000), albeit augmented with a real-balance term. This specification imposes a unit elasticity of intertemporal substitution in consumption, while φ governs relative risk aversion. As $\varphi \to 1$, preferences approach the expected-utility case. When $\varphi > 1$, the household is more risk averse than in the expected-utility case (i.e., the $\exp(\sigma U_{t+1})$ term raises risk aversion for an unchanged degree of intertemporal substitution). In such an environment, agents have a greater inherent desire for a steady and predictable evolution of consumption. The opposite set of desires holds for $\varphi < 1$. Because of the distinction between period utility U_t and its standard component V_t, it is convenient for the household optimization problem to have a Lagrange multiplier with which to carry the definition of U_t; this multiplier is denoted Ω_t. As will become clear below, this Lagrange multiplier captures the impact of risk aversion on consumer behavior in the nonlinear model.

In maximizing intertemporal utility, the household faces a sequence of budget constraints like:

$$C_t + E_t[Q_{t,t+1}\frac{B_{t+1}}{P_{t+1}}] + M_{t+1} = \frac{B_t + M_t}{P_t} + \frac{W_t}{P_t}N_t + D_t - T_t, \qquad (13)$$

where B_{t+1} denotes a portfolio of nominal claims on the complete contingent claims market, $Q_{t,t+1}$ the stochastic discount factor, W_t the nominal wage, T_t a real lump-sum tax, and D_t real dividend income.

The resulting household consumption Euler equation can be written as:

$$\beta E_t \left\{ \left[\frac{\exp(\sigma U_{t+1})}{E_t[\exp(\sigma U_{t+1})]} \right] \left(\frac{C_{t+1}}{C_t} \right)^{-1} \frac{R_t}{\Pi_{t+1}} \right\} = 1. \qquad (14)$$

This condition indicates that, notwithstanding logarithmic preferences, the parameter σ matters for consumption growth and the real interest rate in the nonlinear model. In the loglinearized economy, however, this condition delivers a standard IS equation,

$$\hat{y}_t = E_t[\hat{y}_{t+1}] - (\hat{R}_t - E_t\hat{\pi}_{t+1}),$$

so that Epstein-Zin preferences and standard preferences are macroeconometrically equivalent in their implications for the IS equation, with the preceding expression corresponding to equation (3) with unit slope.

Epstein-Zin preferences also matter for price-setting choices (which, as before, are subject to Calvo obstacles to price adjustment). In particular, the expressions for Z_{1t} and Z_{2t} are as follows:

$$Z_{1t} = \beta \xi E_t \left\{ \frac{\exp(\sigma U_{t+1})}{E_t[\exp(\sigma U_{t+1})]} \Pi_{t+1}^{\epsilon-1} Z_{1t+1} \right\} + 1$$
$$Z_{2t} = \beta \xi E_t \left\{ \frac{\exp(\sigma U_{t+1})}{E_t[\exp(\sigma U_{t+1})]} \Pi_{t+1}^{\epsilon} Z_{2t+1} \right\} + MC_t, \tag{15}$$

with the optimal price contract continuing to be $\widetilde{P}_t^* = \frac{\epsilon}{\epsilon-1} \frac{Z_{2t}}{Z_{1t}}$.

These expressions reflect the impact that Calvo impediments to price changes have in the world of Epstein-Zin preferences. Calvo price stickiness is particularly burdensome on agents in this environment. Firms are owned by and serve to maximize profits for households with Epstein-Zin preferences, and Calvo pricing produces a type of indefinite uncertainty that is penalized heavily by this preference structure. While probabilities can be assigned to the date at which firms will be permitted to readjust prices, no date can be specified with certainty, and the protracted lack of resolution of uncertainty means a loss of utility. The ratio of exponents in the pricing expressions is the adjustment that firms make to their price-setting plans to compensate for the protracted period of risk. Nevertheless, the model with Epstein-Zin preferences does produce, when loglinearized near the steady state, a pricing equation that is the same as the prototypical New Keynesian Phillips curve; details of this derivation are provided in our Technical Appendix.

5.2   Implications for optimal monetary policy

Let us now consider optimal monetary policy under commitment. Uhlig (2006) describes the Ramsey program in a flexible-price economy characterized by Epstein-Zin preferences, and this program can be adapted to monetary policy analysis and to the presence of price stickiness by drawing on the techniques described in Khan, King, and Wolman (2003).

The focus here is on the case where fiscal policy (specifically, a subsidy to firms) is not used to offset the distortion associated with monopolistic competition in goods market. The first-best

allocation is therefore not an option, even in steady state. Furthermore, as noted above, unexpected changes in utility flows enter firms' discount-factor expression, and so affect pricing decisions when the price is likely to remain fixed for several periods. This externality, which is transmitted from the financial market to goods markets, needs to be internalized by the Ramsey planner. This element of the problem, absent in the expected-utility world, can materially affect optimal inflation and the desired output gap path.

In this connection, it is worth drawing attention to the role of the definition of U_t as a constraint on optimal policy under Epstein-Zin preferences. Let $\tilde{\Omega}_t$ denote the Lagrange multiplier on this constraint in the Ramsey program. If $\tilde{\Omega}_t = 0$ for all t, the constraint is not binding; maximizing the intertemporal stream of U_t involves the same policy as maximizing the intertemporal stream of standard expected utility V_t; and Epstein-Zin preferences have no material impact on monetary policy design. On the other hand, if in general $\tilde{\Omega}_t$ is nonzero, the constraint binds and the replacement of standard preferences by Epstein-Zin preferences has a bearing on optimal monetary policy. With this in mind, it is appropriate to proceed to our results for optimal monetary policy in the Epstein-Zin utility framework.[9]

There is no microeconomic dissonance with respect to long-run policy. That is, in the deterministic steady state, the optimal inflation rate is the same across the worlds of expected utility and Epstein-Zin utility. Let the technology shock take the value $A_t = 1$ for $t = 0, 1, \cdots, \infty$. With no shocks in the economy, there is no call for compensation for risk, so $\frac{\exp(\sigma U_{t+1})}{E_t[\exp(\sigma U_{t+1})]} = 1$ for $t = 0, 1, \cdots, \infty$. This in turn implies that $\tilde{\Omega}_t = 1$ for $t = 0, 1, \cdots, \infty$; i.e., the constraint that defines Epstein-Zin utility binds but leaves other equilibrium conditions unaltered. The nonlinear Euler equation is therefore the same across expected-utility and Epstein-Zin cases in the long run; and with parallel optimality conditions across the two preference settings, optimal steady-state inflation rates are also identical.

By contrast, differences with the expected-utility case quickly emerge when loglinear dynamics of the stochastic economy under optimal policy are considered. While the loglinear IS equations

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[9]A more detailed analysis appears in Levin, López-Salido, and Yun (2007b) and in the Technical Appendix that supplements the present paper.

coincide across the expected-utility and Epstein-Zin worlds, the welfare function does not, and so the social planner's first-order conditions that help determine aggregate dynamics differ across the two cases.

There being no subsidy, the planner's optimality conditions are loglinearized near a steady state which is distorted by monopolistic competition, and which therefore does not correspond to the efficient allocation. Money holdings are now assumed absent; the monetary-frictions rationale for deviating from zero inflation is therefore taken off the table, so simplifying the analysis of the first-order dynamics of optimal policy.

Parameter choices follow Tallarini (2000), who simulated with a risk-aversion parameter set, φ: (1, 10, 25, 100). β is set at 0.9926, φ at 10, and $\varphi_0 = 2.99$ as a benchmark parameterization. In addition, the logarithm of aggregate labor (and total factor) productivity follows $\log A_t = 0.95 \log A_{t-1} + \epsilon_t$, where ϵ_t is i.i.d. white noise. As Tallarini (2000) shows, the relative risk-aversion coefficient with the form of Epstein-Zin utility specified above is $(\varphi + \varphi_0)/(1 + \varphi_0)$. This implies a relative risk-aversion coefficient of 1.0 if expected-utility preferences are used, but 3.26 with Epstein-Zin preferences—so there is more relative risk aversion in the latter case.

The Lagrange multiplier for the planner's optimization devolves to a constant when preferences are described by expected utility. Thus, the difference between expected-utility and Epstein-Zin preferences is that with the expected-utility formulation the Lagrange multiplier is zero when expressed as a log-deviation from its steady-state value—that is, $\hat{\Omega}_t = 0$ for $t = 1, \cdots, \infty$—while under Epstein-Zin preferences it can fluctuate.

Figure 4 compares optimal policy under Epstein-Zin preferences with that under expected utility, as reflected in dynamic responses of output and inflation to an exogenous rise in productivity. Under expected utility, the optimal policy keeps inflation constant while the path of output tracks its flexible-price trajectory. In contrast, Epstein-Zin preferences imply that social welfare depends on the volatility of aggregate output, not just on the variances of the output gap and the inflation rate. Thus, the optimal policy response to the positive productivity shock is significantly tighter and thereby reduces its initial impact on the level of output, albeit at the cost of a small and

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transitory deflation.

We have shown that, up to a first-order approximation, the optimal monetary policy response to stationary technology shocks is affected by the imposition of Epstein-Zin preferences. This result must be qualified by observing that, had a subsidy been available to offset the steady-state monopoly distortion, the adoption of Epstein-Zin preferences would not have produced any difference (up to first order) in optimal monetary policy.

6   Resolving macroeconometric equivalence using financial data

Clearly, the alternatives of expected-utility and Epstein-Zin preferences create another example of the equivalence/dissonance dilemma for monetary policy design. But financial data could break IS equation macro-equivalence. As shown in the previous section, the expected-utility and Epstein-Zin preference specifications deliver the same IS equation. While the two specifications differ in the functional form of period utility U_t and so of marginal utility $U_{C,t}$, the loglinear approximations of marginal utility are identical; and it is the loglinear approximation that matters for the IS equation. Determining empirically the appropriate preference specification requires exploring cases where the higher-order approximations of $U_{C,t}$ matter materially for data outcomes. But, as noted above, the difficulty in uncovering nonlinear structure in aggregate macroeconomic dynamics rules out macro series as a likely source of such cases.

Instead, financial data may be better candidates, since the finance literature is replete with cases where asset price behavior is related to functions of U_t and where higher-order terms (e.g., consumption volatility) impact significantly on data. These financial-economics experiments do not fall into the category of macroeconomic applications, either because the data are sampled so frequently (as with daily data) that observations on most macroeconomic series are unavailable, or because the hypotheses are conditional on assumed exogenous processes for series that would be explained endogenously in a macroeconomic application. Yet, by isolating testable empirical implications of nonlinearities, these exercises can help macroeconomists decide between different specifications of macroeconomic structure. Higher-order properties of models, despite their subdued

impact on macroeconomic time series dynamics, are an important source of financial market dynamics. For this reason, from *positive-economics* studies of financial data we can glean information necessary for accurate welfare calculations in *normative* macroeconomic applications.

A major example of an attempt to discriminate between Epstein-Zin and standard preferences in an empirical financial economics context is Bansal and Yaron (2004). Bansal and Yaron use monthly data, but theirs is a financial rather than macroeconomic study: the consumption equation consists of a univariate law of motion. Bansal and Yaron thus treat consumption growth as an exogenous state variable (rather than the endogenous variable it would be in macroeconomic applications) and use the nonlinear Euler equation (vs. the use of the loglinearized version in macroeconomics). Bansal and Yaron derive the implications for asset market behavior that arise jointly from Epstein-Zin preferences and their assumed law of motion for consumption. They conclude that these can account for "the observed magnitudes of the equity premium, the risk-free rate, and the volatility of the market return, dividend yield and the risk-free rate" (2004, p. 1502). Bansal (2007, p. 297) provides a catalogue of further empirical strengths of this model, arguing that it or close variants can account for nominal yield curve and foreign exchange behavior.

The existing literature clearly puts forward some empirical advantages of Epstein-Zin preferences over the expected-utility baseline, and therefore reasons for favoring Epstein-Zin in deriving the IS curve. A further simple illustration of the power of financial data to test macroeconomic models is now provided, focusing on real yield curve behavior. This example reinforces the message that the alternative preference specifications studied here imply sharply different implications for financial behavior, while also bringing out some empirical limitations of both specifications.

The slope of the real yield curve is a central regularity with which to test the relative merits of Epstein-Zin and expected-utility preference specifications. Piazzesi and Schneider (2006) establish, in a model without production, that Epstein-Zin preferences are associated with a downward-sloping real yield curve—a departure from the basically flat implication of expected-utility preferences for the same intertemporal-substitution elasticity (namely, unity). On the basis of this result, it would seem that the different term-structure behavior across the two preference specifications

can be used to resolve equivalence of linearized IS curves in macroeconomic models.

Figure 5(a) plots real yield curve data as predicted by the Bansal-Yaron (2004) model. The figure uses both an intertemporal elasticity of substitution away from unity (Bansal and Yaron's parameter choice) and an elasticity of unity (in line with the preferences specified in Section 5). Bansal and Yaron's parameterization of the consumption process is followed here, but risk aversion is set to 5.0 when the elasticity of intertemporal substitution is unity and at 15 for the case of a 1.5 intertemporal elasticity. The figure shows that Epstein-Zin preferences predict a downward-sloping real yield curve irrespective of the degree of intertemporal substitution contemplated.

Figure 5(b) displays average real yield curves, drawn from the indexed bond market, of France, the United Kingdom, and the United States for the five-year period 2003-2007. This covers a lengthy economic expansion and corresponds to a period over which indexed bond markets were well established in all three economies (the U.K. market was of long standing; the French market had adjusted to euro introduction in 1999-2002; and the U.S. market had become much more liquid).[10] French and U.S. real yield curves appear on this evidence to be upward-sloping, while the UK real yield curve is flat or downward-sloping, in line with Piazzesi and Schneider's (2006) finding that the U.K. real yield curve has a downward slope.

The real yield patterns observed empirically thus contradict *both* the Epstein-Zin specifications and the expected-utility specification because neither specification predicts the upward-sloping real yield curves predominant in the data. This example underscores the merits offered by financial data for macroeconomic behavior. Financial data bring out inadequacies of macroeconomic model specification that cannot be detected in a macroeconometric study; therefore, such bodies of data offer powerful tests for models used in monetary policy analysis.

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[10]There are two datasets available for U.S. real yields: the website of J. Huston McCullogh and the U.S. Treasury. McCullogh interpolated real yield curves from U.S. TIPS data from 1998, while real yields on the U.S. Treasury website begin in 2003. The Bank of England reports interpolated real yield curves from indexed securities; the shortest maturity available on a consistent basis is 2.5 years. France's bonds are indexed to the French CPI (source: Agence France Tresor website); its real yield curve is calculated using the Nelson-Siegel (1987) procedure.

7   Conclusions

The preceding analysis has illustrated the consequences for optimal monetary policy of models which feature macroeconometric equivalence and microeconomic dissonance. Alternative versions of a small New Keynesian model were presented that are isomorphic in their implied linearized macroeconomic dynamics, but whose underlying microeconomic differences return to the surface when welfare in the fully nonlinear model is analyzed. It was shown that optimal monetary policy is sensitive to the specification of economic structure even when the specifications are equivalent in their implications for the slope parameters of the IS and Phillips curves. The welfare differences across specifications are manifested in variations in period-by-period optimal policy in the stochastic economies and in different optimal steady-state inflation rates. Our conclusion is that macroeconomic applications are unlikely to break the equivalence, even those deploying nonlinear estimation methods. But financial data can break the equivalence by determining the nonlinear structure of household preferences and so revealing the underpinnings of the IS equation. Likewise, microeconomic data are revealing about Phillips curve structure because they shed light on aspects of the firm's optimization problem that are aggregated out of macroeconomic data. Together, these alternative datasets serve as an important discipline on monetary policy analysis, as they can deliver empirical rejections of models whose predictions were consistent with the macroeconomic data.

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Figure 1. Comparison of Dixit-Stiglitz and Quasi-Kinked Demand Curves
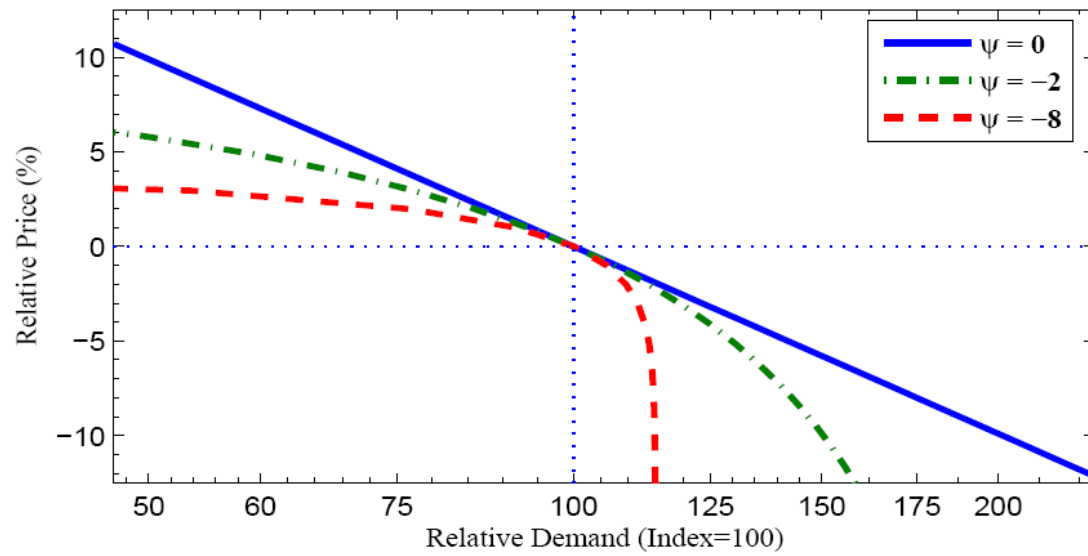
Figure 2. Optimal Steady-State Inflation Rate: Alternative Sources of Real Rigidity
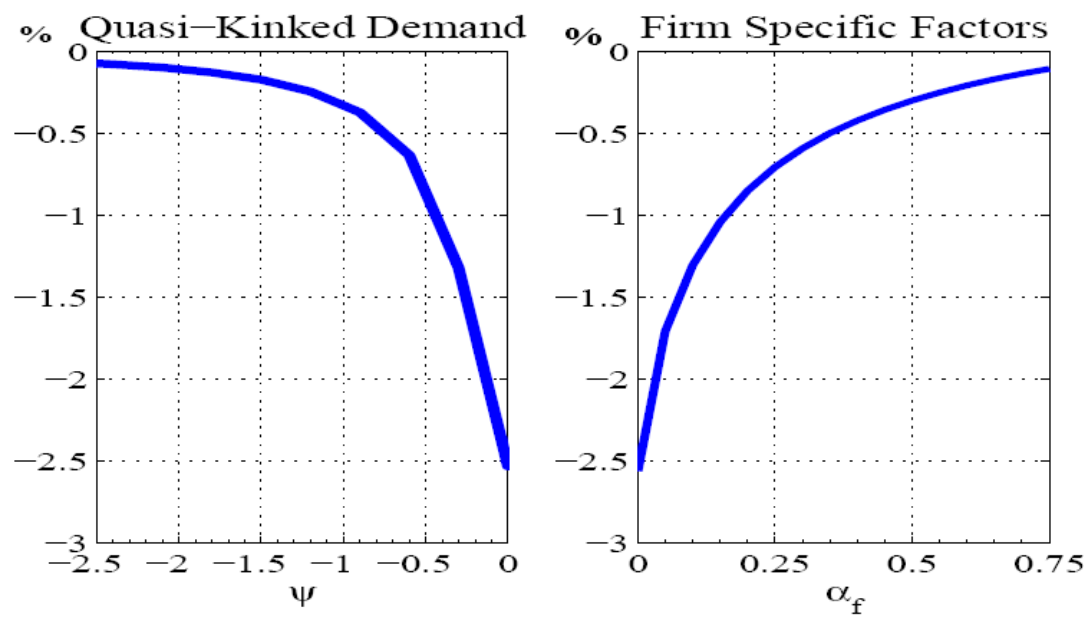
Figure 3. The Welfare Costs of Relative Price Distortions
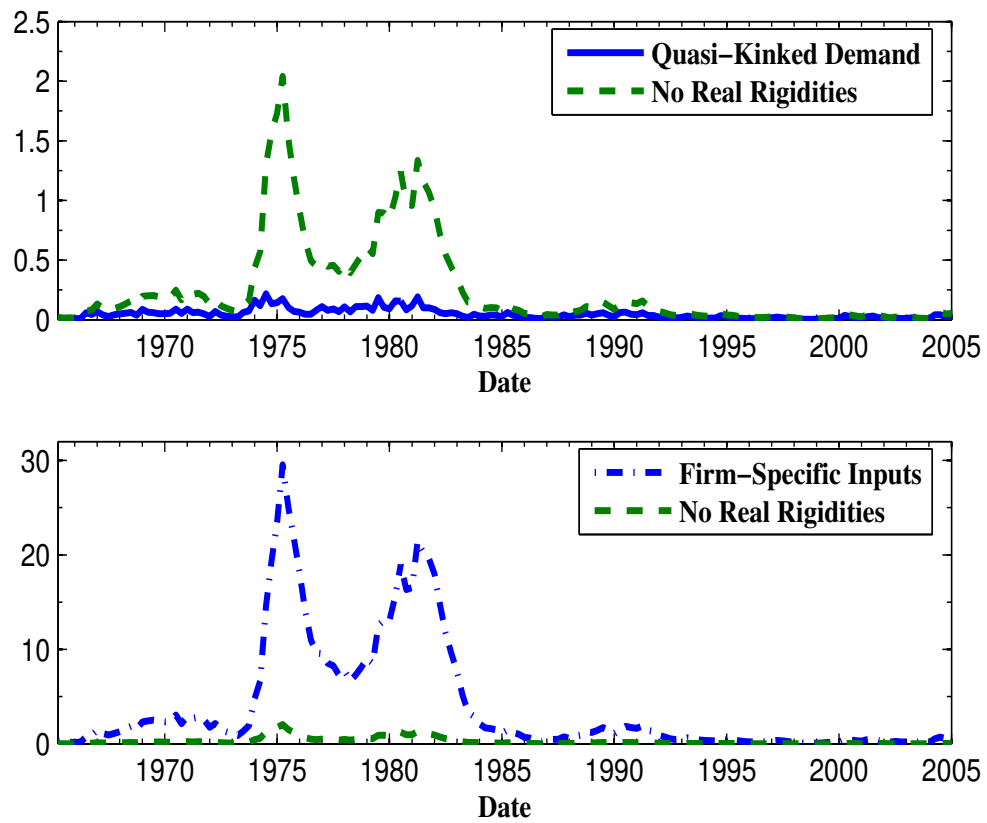Under Alternative Sources of Strategic Complementarity

Figure 4. Impulse Response for Technology Shock under Optimal Monetary Policy:
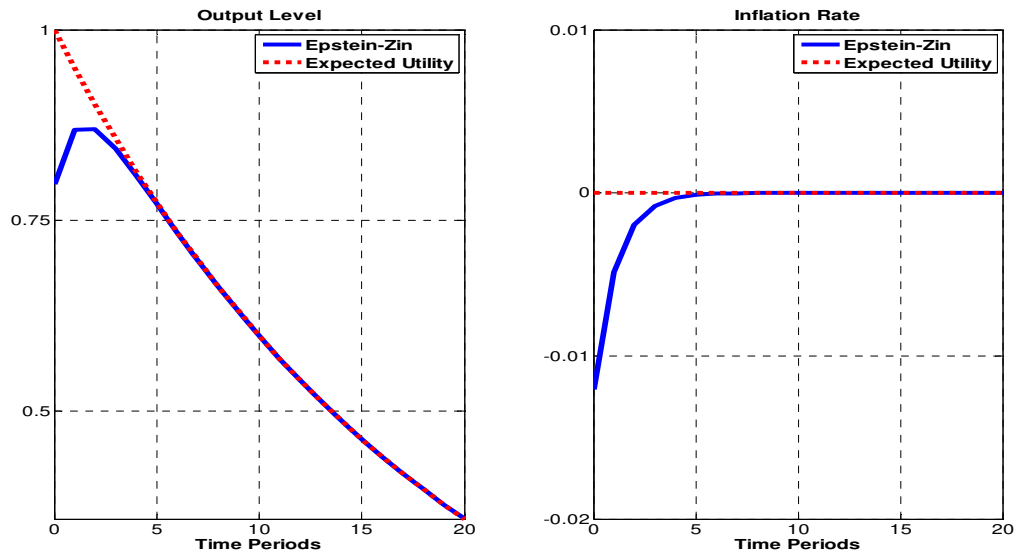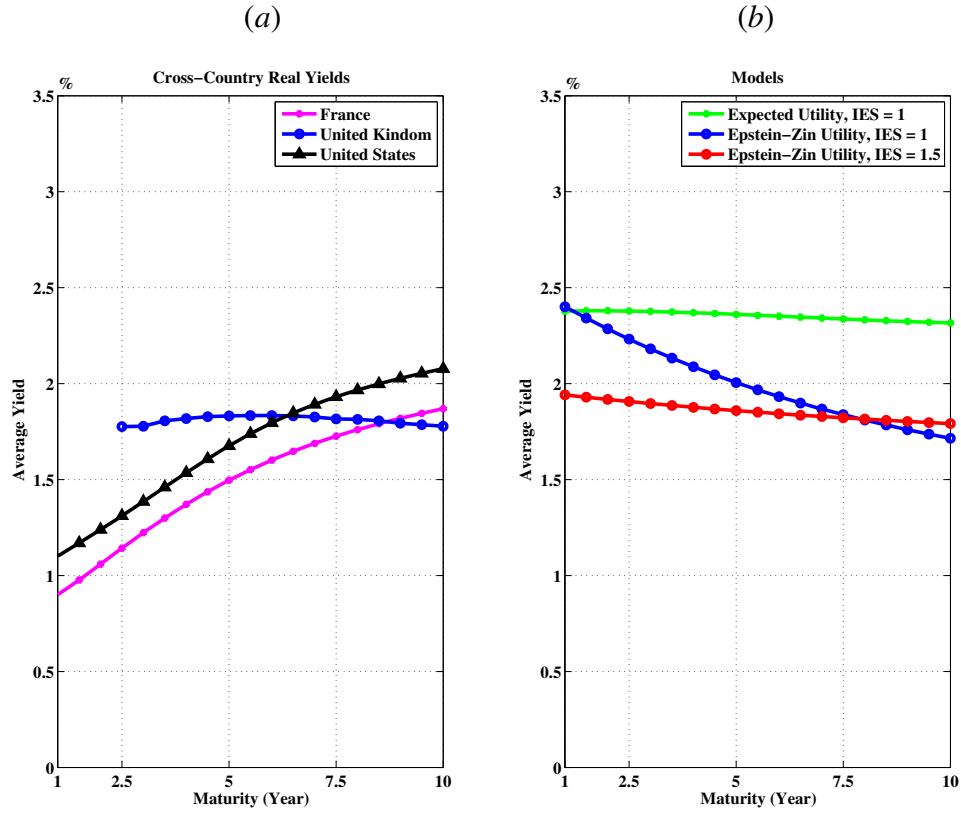Epstein-Zin and Expected-Utility Preferences

Figure 5. Real Yield Curves across Countries vs. Model Predictions

Note: Figure 5(*b*) uses the same law of motion for consumption under both expected utility and Epstein-Zin utility. The implied level of the real yield curve will still differ across specifications; therefore, the figure rescales the level of the expected-utility curve to allow direct comparisons of curvature across expected-utility and Epstein-Zin specifications.