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Firm-specific capital, nominal rigidities and the business cycle ☆

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ABSTRACT

This paper formulates and estimates a three-shock U.S. business cycle model. The estimated model accounts for a substantial fraction of the cyclical variation in output and is consistent with the observed inertia in inflation. This is true even though firms in the model re-optimize prices on average once every 1.8 quarters. The key feature of our model underlying this result is that capital is firm-specific. If we adopt the standard assumption that capital is homogeneous and traded in economy-wide rental markets, we find that firms re-optimize their prices on average once every 9 quarters. We argue that the micro implications of the model strongly favor the firm-specific capital specification.

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1. Introduction

Macroeconomic data indicate that inflation is inertial. To account for this inertia, macro modeler embed assumptions that are either implausibe on a priori grounds or directly in conflict with micro data. For example, in many new-Keynesian macroeconomic models, firms index non-optimized prices to lagged inflation. These models account for inflation inertia by assuming that firms re-optimize their prices every six quarters or even less often.[1] Other new-Keynesian models don't allow for indexing to lagged inflation. In estimated versions of these models, firms change prices once every two years or

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[1] For example, Eichenbaum and Fisher (2007) find that estimated versions of Calvo pricing models with indexing to lagged inflation imply that firms re-optimize prices roughly once every six quarters. Smets and Wouters' (2003) estimated model implies that firms re-optimize prices on average once every nine quarters.

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less often.[2] This property contrasts sharply with findings in Bils and Klenow (2004), Golosov and Lucas (2007) and Klenow and Kryvtsov (2008) who argue that firms change prices more frequently than once every two quarters.[3]

In this paper we formulate and estimate a model which is consistent with the evidence of inertia in inflation, even though firms re-optimize prices on average once every 1.8 quarters.[4] In addition our model accounts for the dynamic response of 10 key U.S. macro time series to monetary policy shocks, neutral technology shocks and capital embodied shocks.[5]

In our model aggregate inflation is inertial despite the fact that firms re-optimize prices frequently. The inertia reflects that when firms do re-optimize prices, they change prices by a small amount. Firms change prices by a small amount because each firm's short run marginal cost curve is increasing in its own output.[6] This positive dependency reflects our assumption that in any given period, a firm's capital stock is pre-determined. In standard equilibrium business cycle models a firm's capital stock is not pre-determined and all factors of production, including capital, can be instantly and costlessly transferred across firms. These assumptions are empirically unrealistic but are defended on the grounds of tractability. The hope is that these assumption are innocuous and do not affect major model properties. In fact these assumptions matter a lot.

In our model, a firm's capital is pre-determined and can only be changed over time by varying the rate of investment. These properties follow from our assumption that capital is completely firm-specific. Our assumptions about capital imply that a firm's marginal cost curve depends positively on its output level.[7] To see the impact of this dependence on pricing decisions, consider a firm that contemplates raising its price. The firm understands that a higher price implies less demand and less output. A lower level of output reduces marginal cost, which other things equal, induces a firm to post a lower price. Thus, the dependence of marginal cost on firm-level output acts as a countervailing influence on a firm's incentives to raise price. This countervailing influence is why aggregate inflation responds less to a given aggregate marginal cost shock when capital is firm-specific.

Anything, including firm-specificity of some other factor of production or adjustment costs in labor, which causes a firm's marginal cost to be an increasing function of its output works in the same direction as firm-specificity of capital. This fact is important because our assumption that the firm's entire stock of capital is predetermined probably goes too far from an empirical standpoint.

We conduct our analysis using two versions of the model analyzed by Christiano, Eichenbaum, and Evans (CEE henceforth, 2005): in one, capital is homogeneous whereas in the other, it is firm-specific. We refer to these models as the homogeneous and firm-specific capital models, respectively. We show that the only difference between the log-linearized equations characterizing equilibrium in the two models pertains to the equation relating inflation to marginal costs. The form of this equation is identical in both models: the change in inflation at time t is equal to discounted expected change in inflation at time $t+1$ plus a reduced form coefficient, γ, multiplying time t economy-wide average real marginal cost. The difference between the two models lies in the mapping between the structural parameters and γ. In non-linear framework, however, it is not true that the solutions to the homogeneous and firm-specific capital models are observationally equivalent with respect to macro data.[8]

In the homogeneous capital model, γ depends only on agents' discount rates and on the fraction, $1-\xi_p$, of firms that re-optimize prices within the quarter. In the firm-specific capital model, γ is a function of a broader set of the structural parameters. For example, the more costly it is for a firm to vary capital utilization, the steeper is its marginal cost curve and hence the smaller is γ. A different example is that in the firm-specific capital model, the parameter γ is smaller the more elastic is the firm's demand curve.[9] This result reflects that the more elastic is a firm's demand, the greater is the reduction in demand and output in response to a given price increase. A bigger fall in output implies a bigger fall in marginal cost which reduces a firm's incentive to raise its price.

The only way that ξ_p enters into the reduced form of the two models is via its impact on γ. If we parameterize the two models in terms of γ rather than ξ_p, they have identical implications for all aggregate quantities and prices in a standard (log-)linearized framework. This observational equivalence result implies that we can estimate the model in terms of γ without taking a stand on whether capital is firm-specific or homogeneous. The observational equivalence result also implies that we cannot assess the relative plausibility of the homogeneous and firm-specific capital models using macro data. However, the two models have very different implications for micro data. To assess the relative plausibility of the

[2] See for example the estimates in Rabanal and Rubio-Ramírez (2005) for the post 1982 era or the NBER working paper 10 617 version of Eichenbaum and Fisher (2007).

[3] For example in calibrating their model to the micro data, Golosov and Lucas (2007) select parameters to ensure that firms change prices on average once every 1.5 quarters.

[4] To maintain contact with the bulk of estimated new Keynesian models we assume that firms index prices to lagged inflation. The NBER working paper 10 617 version of Eichenbaum and Fisher (2007) establishes that the introduction of firm-specific capital has similar effects in models with and without indexation to lagged prices.

[5] See also DiCecio (2009) for a multi-sectoral general equilibrium model which allows for the same shocks that we consider. Also Edge et al. (2003) consider a general equilibrium model with two types of technology shocks. Galí, López-Salido and Vallés (2002) consider neutral technology shocks only.

[6] For early discussions of this idea, see Ball and Romer (1990) and Kimball (1995).

[7] A closely related assumption that generates an upward sloping marginal cost curve is that there are internal costs of adjusting capital.

[8] See Levin et al. (2008) who emphasize this point and analyze the nature of optimal policy in the non-linear versions of the two models.

[9] See Ball and Romer (1990) and Kimball (1995) for an early discussion of this point.