Federal Reserve Bank of New York
Staff Reports

Globalization and Inflation Dynamics: The Impact of Increased Competition

Argia M. Sbordone

Staff Report no. 324
April 2008

This paper presents preliminary findings and is being distributed to economists and other interested readers solely to stimulate discussion and elicit comments. The views expressed in the paper are those of the author and are not necessarily reflective of views at the Federal Reserve Bank of New York or the Federal Reserve System. Any errors or omissions are the responsibility of the author.

Globalization and Inflation Dynamics: The Impact of Increased Competition
Argia M. Sbordone
Federal Reserve Bank of New York Staff Reports, no. 324
April 2008
JEL classification: E31

Abstract

This paper analyzes the potential effect of global market competition on inflation dynamics. It does so through the lens of the Calvo model of staggered price setting, which implies that inflation depends on expected future inflation and a measure of marginal costs. I modify the assumption of a constant elasticity of demand, standard in this model, to provide a channel through which an increase in the number of traded goods may affect the degree of strategic complementarity in price setting and hence alter the dynamic response of inflation to marginal costs. I first discuss the behavior of the variables that drive the impact of trade openness on this response, and then I evaluate whether an increase in the variety of traded goods of the magnitude observed in the United States in the 1990s might have a significant quantitative impact. I find that it is difficult to argue that such an increase in trade would have generated a sufficiently large increase in U.S. market competition to reduce the slope of the inflation-marginal cost relation.

Key words: inflation dynamics, globalization

Sbordone: Federal Reserve Bank of New York (e-mail: argia.sbordone@ny.frb.org). The views expressed in this paper are those of the author and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

The policy debate about the macroeconomic effects of globalization has centered on two main themes: that globalization has contributed to bring down US inflation, and that it has affected the sensitivity of inflation to output fluctuations. Several recent policymakers speeches have addressed the issue of whether more intense competition, generated by the increase in trade experienced since the '90s, has changed the role of domestic factors in shaping the inflation process. Chairman Bernanke (2007), for example, has underlined how the dependence of factor markets from economic conditions abroad might have reduced the market power of domestic sellers, how the pricing power of domestic producers might have declined, and how lower import prices both of final and intermediate goods might have contributed to maintain overall inflation at low levels. Similarly, President Yellen (2006) and Governor Kohn (2006) have discussed several direct and indirect impacts of more global markets on US inflation.

In this paper I explore how globalization might have impacted US inflation by using the new Keynesian model of inflation dynamics as analytical framework. Within this framework, I focus in particular on the effects that an increase in market competition generated by an increase in trade might have on the sensitivity of inflation to real marginal costs of production.

The relationship between inflation and marginal cost is a key determinant of the overall 'slope' of the new Keynesian Phillips curve (NKPC), which links the dynamics of inflation to the level of economic activity. In the price setting model most often used to derive the NKPC (the one based on the contribution by Calvo, 1983), this relationship depends primarily on the frequency of price changes, but it is also affected by strategic complementarity in price setting. It is this last mechanism that provides a way of formalizing the 'globalization' argument, according to which the increase in the openness of the economy has affected the sensitivity of inflation to output variations.

I depart here from the assumption of constant elasticity of substitution among differentiated goods, which is typically made in the Calvo model, and adopt a specification where the elasticity is a function of the firm's relative share of the market. This implies that changes in the importance of trade that affect relative market shares affect in turn the elasticity of demand faced by firms, and hence their desired mark-ups, and so ultimately may have an impact on the elasticity of aggregate inflation to real marginal costs and the slope of the Phillips curve.

To preview the results: I find that an increase in the number of goods traded is able to generate the sort of real rigidities that may lead to a change in the slope of the Phillips curve. The sign of the change, however, depends on how fast the elasticity of substitution among goods increases, and different parametrizations of the demand function may lead to different answers. For large enough increases in the number of goods traded, the slope of the Phillips curve is in general declining: however, the evidence on trade patterns so far provides little ground to assume that we are yet in the declining portion of the curve.

There are a number of caveats to these results. In particular, the elasticity of inflation to marginal cost is only one of the determinants of the slope of the Phillips curve - the overall response of inflation to output (or output gap) - and its increase or decline does not necessarily imply that the latter is of the same sign. However, this is arguably the component that is affected the most by variations in the degree of market competition and it is the one relied upon in discussions of the effects of global competition on the "pricing power" of domestic firms; hence it is the one where a study of these variations should be centered. I return to this point in the conclusion.

The paper is organized as follows. Section 2 overviews existing evidence about the change in the slope of the Phillips curve and discusses the ensued debate. Section 3 analyzes the channels through which the increased trade that characterizes globalization may affect the dynamics of inflation. Section 4 introduces the analytical framework that is used to pin down these effects, and section 5 adapts the framework to analyze the effects of firms' entry on the dynamics of price adjustments. Sections 6 and 7 evaluate the quantitative impact of trade increase on the marginal cost slope of the Phillips curve, and section 8 concludes.

2 Has the slope of the Phillips curve changed?

The policymakers' concerns over a change in the slope of the Phillips curve in recent years derive from its role in assessing the cost of disinflation. A flatter Phillips curve carries the implication that, for a given degree of inflation persistence, reducing inflation involves a higher 'sacrifice ratio' than otherwise, namely it requires enduring a longer period of unemployment above the natural rate for every desired percentage point of reduction in inflation. On the other hand, as noted by Mishkin (2007), a flatter Phillips curve also implies that an overheated economy will tend to generate a smaller increase in inflation.

Most of the empirical analyses supporting the policymakers' concerns address the issue of the flattening of the Phillips curve in the context of traditional 'accelerationists' Phillips curves. Roberts (2006) and Williams (2006), for example, estimate smaller Phillips curves' slopes in samples covering the post-84 period. Williams in particular analyzes samples with moving starting points - from 1980:1 to 1999:4, but with a fix end point (2006:4) and finds evidence of a flatter curve and a higher sacrifice ratio in the samples that start in the 1990s relative to those estimated in the full sample. However, he also finds that in the more recent samples the unit sum restriction on the lag coefficients, which defines the accelerationist curve, is violated. Furthermore, when in these samples the lag coefficients are left unconstrained, the estimates of the slope coefficient indeed increases.

An alternative source of evidence that the slope of the Phillips curve has declined in more recent samples is provided by estimates in the context of general equilibrium models. Boivin and Giannoni (2006), for example, estimate that the coefficient of marginal cost in a new Keynesian Phillips curve (NKPC) declines from .011 to .008 in the post '84 period; Smets and Wouters (2007) in a similar general equilibrium model report that the estimated interval between price changes is higher in the 1984-2004 sample relative to the 1966-1979 period, which imply that the slope declined in the more recent period.

While the just cited studies aim at relating the change in the inflation-output trade-off to the change in monetary policy that took place in the early '80s, in a recent BIS study Borio and Filardo (2007) link instead variations in the slope of the Phillips curve to globalization. Specifically, they estimate a traditional Phillips curve for many countries over the two periods 1980-1992 and 1993-2005, and document that in the more recent period there has been both a decline in the autoregressive coefficient - hence a decline in inflation persistence, and a decline in the slope, hence a drop in the sensitivity of inflation to domestic output gap. For the United States, in particular, the authors report a decline in the estimated coefficient of lagged inflation from .92 to .82 across the two samples, and a decline in the elasticity of inflation to output gap from .13 to .09. They take this evidence as the starting point of the investigation of a 'global slack' hypothesis, according to which the decline in the sensitivity of inflation to domestic measures of output gap is explained by the fact that global measures of demand pressure have become in the later period the main driving force of inflation dynamics.

A successor study (Ihrig et al. 2007) finds that the purported support for the global slack hypothesis is not robust to the specification of the measures of global slack. For example, the study finds that variables such as domestic output time the ratio of trade to GDP, and import prices time the ratio of imports to GDP do not have statistically significant coefficients. The study, however, does not dispute the evidence that the Phillips curve appears to have flattened since the '90s; it contests the interpretation that this is indeed an effect of globalization. Overall, the authors in fact conclude that the estimated effect of foreign output gaps is in general insignificant, that there is no evidence that the trend decline in the sensitivity of inflation to domestic output is due to globalization, nor they find increased sensitivity of inflation to import prices.

An IMF study (2006) also estimates traditional inflation regressions where the coefficient on the slack variable interacts with measures of central bank credibility and openness of the economy. The study estimates a negative coefficient on the interaction term between domestic output gap and trade openness, measured by the share of non-oil imports in GDP, and interprets this result as evidence that the increase in trade has contributed to the decline of the slope of the Phillips curve. The study, however, examines the group of advanced economies as a whole, and doesn't present results for the US alone. Finally, in the context of a similar traditional Phillips curve estimated for the U.S., Ball (2006) allows interaction of the output coefficient with trade, and finds only a modest effect.

In this paper I do not estimate the slope of the Phillips curve, but propose instead a way to analyze the quantitative importance of globalization effects on such a slope. Specifically I lay down the channels through which an increase in market competition can generate a flattening of the Phillips curve, in the context of the new Keynesian model of inflation dynamics.

3 Channels of globalization effects on inflation

The basic channel emphasized both in policy debates and empirical studies as potential carrier of globalization effects on inflation dynamics is trade integration, which especially when accompanied by policy incentives, is argued to bolster competition. Increased competition, the argument goes, creates two effects: a direct effect of containment of costs, by restraining increases in workers' compensations and reducing real import prices, and a second, indirect effect of creating pressure to innovate, which contributes to increasing productivity. Higher productivity in turn further lowers production costs: if markups are constant, lower production costs reduce the pressure on prices. But the margins that firms are willing to charge over their costs might be reduced as well, moderating the extent of price increases.

To understand how these effects work, it is useful to decompose the relation between consumer price inflation and domestic output, the one typically analyzed in empirical studies, in three distinct parts. First, there is the relation between CPI inflation and domestic inflation. In an open economy, consumer price inflation reflects the price dynamics of goods produced both domestically and abroad that are consumed at home. Secondly, there is the relation between domestic inflation and the marginal cost of production, and finally the relationship between the marginal cost of production and domestic output.

The central relationship, that describes how variations in marginal cost translate into fluctuations in domestic prices, is the one most likely affected by an increase in competition.

When analyzed through the lenses of the new Keynesian approach to the construction of a Phillips curve, the strength of this relationship depends on a number of factors. The first is the frequency of price revisions: the longer prices are kept fixed, the more nominal disturbances translate into real effects, rather than aggregate inflation. This is referred to as the nominal rigidity component. The second component is the sensitivity of the desired firms' price to marginal costs versus other prices. If price setters take into account other firms' prices when they set their own price, then the presence of even a small number of firms that do not change their price induces flexible-price firms to change their price by a lesser amount. A third component is the sensitivity of marginal costs to the own output of the firm (versus its sensitivity to the average marginal cost): when marginal costs of the price setter are increasing in its own output, the desired price increase is smaller because the firm takes into account the decline in marginal cost due to the loss in demand when the price is increased. Finally, the pricing decisions are affected by the sensitivity of the firm's own output to its relative price, namely by how elastic is the demand curve of the individual producer. The last three components are commonly referred to as 'strategic complementarity' or 'real rigidity' channels.[1]

Both nominal and real rigidities are known to be important in assessing the size of the 'slope' of the new Keynesian Phillips curve with respect to marginal costs. They have been analyzed in theoretical works and explored in empirical studies aiming at reconciling estimated 'slopes' with reasonable degrees of nominal rigidity.[2]

In this paper I focus on the real rigidity component and analyze how it can be affected by the openness of the economy, through the increase in competitiveness generated by an increase in the number of goods traded in the economy.

To do this I borrow from the new trade literature, and in particular from a recent contribution by Melitz and Ottaviano (2005), who present a model of trade with monopolistic competition and firm heterogeneity to study the effect of trade liberalization on productivity

[1] See Woodford (2003) ch. 3. The term 'real rigidity' was introduced, I believe, by Ball and Romer (1989).

[2] See literature cited later.

and mark-ups. The authors show that import competition induces a downward shift in the distribution of markups across firms. A key element of their model is the dependence of the elasticity of demand upon the relative size of the market. This setting has been used in a macro general equilibrium model by Bilbiie et al (2006a and 2006b) to study endogenous entry as a propagation of business cycles, and the efficiency properties of the model, adopting a framework of flexible prices.

Here I study instead a model of staggered prices. I consider a monopolistically competitive market where there is a fixed entry cost, and a given distribution of firms. A reduction in the individual firms production costs moves up the firms' distribution curve, making profitable for more firms to enter the market. The resulting increase in the variety of goods traded increases the overall degree of competition: this is captured in the model by making the demand elasticity, and hence the mark-up, vary with the number of goods that are traded. Variable mark-ups in turn impact the price setting process and the dynamics of the relationship between inflation and marginal cost.

My focus is specifically on how the process of new entries and the interaction of firms in the price setting process affect the relationship between aggregate inflation and marginal costs. I will not discuss the other two components of the CPI inflation - domestic output relationship that I described, the relation between domestic and CPI inflation, and the relation between marginal cost and domestic output. These relationships obviously matter for the assessment of the overall effect of openness on the Phillips curve's slope, and an explicit modeling of the Phillips curve in open economy may as well illustrate that its slope is lower than that of the closed economy.[3] Nevertheless, understanding the channels through which market entry changes the degree of real rigidity, and how that may emphasize or reduce the inflation-output trade-off, is of primary importance.

Similarly, I will not discuss effects of globalization on inflation of the kind argued by Rogoff (2003, 2006), that in a global environment central banks have less incentive to inflate the economy. Although this lower incentive is another effect of the increased competitiveness of the economy, it is related to central banks' incentives,[4] rather than to the market mechanisms to which I am interested in here.

[3]Several aspects of the difference between open and closed economy are discussed by Woodford (2007, in this volume).

[4]The increase in competitiveness on one hand reduces the monopoly wedge that determines the inflation bias of the central bank, and on the other makes prices and wages more flexible, reducing the real effects of unanticipated monetay policy, hence the gain from inflating.

4 A structural framework

The Calvo model of staggered prices provides a useful framework to disentangle the various theoretical channels that compose the inflation-marginal cost relationship. Since the baseline model is well known, here I summarize its main features to set the stage for the generalizations that I discuss next.

The model has a continuum of monopolistic firms, indexed by i, which produce differentiated goods, also indexed by i, over which consumers' preferences are defined. Firms produce with a constant returns to scale technology and have access to economy-wide factor markets. The optimal consumption allocation determines the demand for each differentiated good $c_t(i)$ as

$$c_t(i) = C_t \left(\frac{p_t(i)}{P_t} \right)^{-\theta} \tag{1}$$

for $\theta > 1$; here $p_t(i)$ is the individual good i price, C_t indicates firm level output, defined by the constant-elasticity-of substitution aggregator of Dixit and Stiglitz:

$$C_t = \left[\int c_t(i)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)}, \tag{2}$$

and P_t is the corresponding aggregate price (the minimum cost to buy a unit of the aggregate good C_t): $P_t = \left[\int p_t(i)^{1-\theta} di \right]^{1/(1-\theta)}$. The model further assumes random intervals between price changes: in every period, only a fraction $(1-\alpha)$ of the firms can set a new price, independently of the past history of price changes, which will then be kept fixed until the next time the firm is drawn to change prices again. By letting α vary between 0 and 1, the model nests assumptions about the degree of price stickiness from perfect flexibility ($\alpha = 0$) to complete price rigidity (the limit as $\alpha \to 1$). The expected time between price changes is then $1/(1-\alpha)$.

The pricing problem of a firm that revises its price in period t is to choose the price $p_t(i)$ that maximizes its expected stream of profits

$$E_t \left\{ \Sigma_{j=0}^{\infty} Q_{t,t+j} \mathsf{P}_{t+j}(i) \right\}, \tag{3}$$

where time t profits $\mathsf{P}_t(i)$ are a function $\mathsf{P}(p_t(i), P_t, y_t(i), Y_t; \Gamma_t)$; $y_t(i)$ is firm's output, defined by (1), $Q_{t,t+j}$ is a stochastic discount factor, and the variable Γ_t stands for all other aggregate variables. The first order condition for the optimal price is

$$E_t \left\{ \Sigma_{j=0}^{\infty} Q_{t,t+j} \mathsf{P}_1 \left(p_t^*, P_{t+j}, y_{t+j}(i), Y_{t+j}; \Gamma_{t+j} \right) \right\} = 0, \tag{4}$$

where the evolution of aggregate prices is

$$P_t = \left[(1-\alpha)\, p_t^{*1-\theta} + \alpha P_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}}. \tag{5}$$

Log-linearizing these two equilibrium conditions around a steady state with zero inflation, with usual manipulations, one obtains the familiar form of inflation dynamics as function of expected inflation and real marginal costs s_t

$$\pi_t = \zeta \widehat{s}_t + \beta E_t \pi_{t+1} \tag{6}$$

where a hat indicates the log-deviation from a non-stochastic steady state, β is the steady state value of the discount factor, and the 'slope' is defined as[5]

$$\zeta = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha}. \tag{7}$$

In this baseline framework, the extent of the nominal rigidity determines how marginal costs translate into inflation fluctuations. In order to consider other potential channels of the kind discussed above the model needs to be generalized.

4.1 The inflation/marginal cost relation: some generalizations

Generalizations of the baseline model can lead to changes in the nominal rigidity component of the slope or introduce some form of real rigidity of the kind discussed previously by adding new terms to expression (7).

One instance in which the nominal rigidity term is modified, despite maintaining an exogenous probability of changing prices, occurs when one allows for a non-zero steady state inflation. In this case the expression for inflation dynamics is derived as a (log) linear approximation of the model equilibrium conditions (4) and (5) around a steady state characterized by positive, rather than zero inflation, as it is the case in the baseline model. Such an approximation modifies the terms in the discount and the rigidity coefficient in the slope (9). As first shown by Ascari (2004), in such a case the slope coefficient would be:

$$\zeta = \frac{\left(1-\alpha\beta\overline{\Pi}^{\theta}\right)\left(1-\alpha\overline{\Pi}^{\theta-1}\right)}{\alpha\overline{\Pi}^{\theta-1}}, \tag{8}$$

where $\overline{\Pi}$ denotes the gross trend inflation rate. The slope in this case depends not only upon the primitives of the Calvo model, the probability of changing prices $1-\alpha$ and the elasticity

[5] Throughout the paper I will use the term slope to indicate the elasticity of inflation to marginal cost, rather than to output.

of demand, but also upon the steady state level of inflation. In this case the *NKPC* has also a richer dynamics, because it includes additional forward-looking terms, unless particular forms of indexation are postulated.[6]

A further modification of the nominal rigidity component is obtained by replacing the assumption of a constant probability of price re-optimization with a state-dependent probability (see Dotsey, King and Wolman 1999).

The generalizations that provide a more direct channel through which the competitive effect of more global markets integration can alter the Phillips curve's slope are those that introduce real rigidity factors in the slope coefficient. Such modifications were at first introduced with the purpose of reconciling empirical estimates of the slope with a degree of nominal rigidity more in line with that documented in firms' surveys.[7] In fact, for any given degree of nominal rigidity, the existence of strategic complementarity lowers the slope or, alternatively, a given empirical estimate of the slope is consistent with a lower degree of nominal rigidity.

Assuming for example that some or all factor markets are firm-specific implies that the marginal cost of supplying goods to the market is not equal for all goods at any specific point in time. In such cases firms' marginal costs depend not only on economy-wide factors, but also on the firm's own output[8] and, for any given increase in marginal cost, this dependence makes the desired price increase smaller. Returning to a baseline case with zero steady state inflation, the slope ζ in these cases becomes

$$\zeta = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha}\frac{1}{1+\theta s_y}, \tag{9}$$

where the strategic complementarity term $\frac{1}{1+\theta s_y}$ depends upon the demand elasticity θ, which measures the sensitivity of the own output of the firm to its relative price, and the sensitivity

[6] If one assumes that non re-optimized prices are indexed at least partly to trend inflation, this additional dynamics is eliminated and the slope is unaffected by the steady state inflation $\overline{\Pi}$. Models with positive trend inflation can be generalized to the case of time-varying steady state inflation; in this case the model describes the dynamics of inflation deviations from a time-varying trend: $\widehat{\pi}_t = \ln(\Pi_t/\overline{\Pi}_t)$). Cogley-Sbordone (2005) estimate a NKPC with time-varying trend inflation. Ireland (2006) and Smets and Wouters (2003), among others, estimate general equilibrium models in the new Keynesian literature allowing for a time varying trend inflation; their assumptions however deliver a time-invariant slope.

[7] For evidence from survey data see for example, Blinder et al. (1998).

[8] Sbordone (2002) discusses this case. A more sophisticated model assumes that capital is endogenously determined, and its limited reallocation is due to the existence of adjustment costs. Woodford (2005) discusses this model, and concludes that the hypothesis of a fixed capital is a good enough approximation. For another empirical application, see Eichenbaum and Fisher (2007).

of the firm's marginal cost to its own output, s_y. The parameter s_y in turn depends on other model assumptions: for example, when labor is traded in an economy-wide labor market but capital is firm specific and therefore cannot be instantaneously reallocated across firms, a constant returns to scale production function implies that s_y is equal to the ratio of the output elasticities with respect to capital and labor.[9] In a more general case where labor markets as well are firm-specific, the parameter s_y is a composite parameter that includes also the elasticity of the marginal disutility of work with respect to output increases (Woodford, 2003).

Another extension is the case in which each firm's desired mark-up over its marginal cost depends upon the prices of other firms. Since the desired mark-up depends on the firm's elasticity of demand, a variable desired mark-up requires a variable demand elasticity. Modeling this case then requires departing from the constant elasticity of substitution assumption of the Dixit-Stiglitz aggregator. For example, the aggregator proposed in the macro literature by Kimball (1995) allows for the elasticity of substitution between differentiated goods to be a function of their relative market share.

Kimball was interested in a variable elasticity of demand to generate countercyclical movements in the firm's desired mark-up, and sufficient real rigidity to make a model of sticky prices plausible (i.e. without having to assume too large a percentage of firms with long periods of unadjusted prices). His objective was to generate more flexible demand functions, particularly 'quasi-kinked' demand functions, characterized by the property that for the firm at its normal market share it is easier to lose customers by increasing its relative price than to gain customers by lowering its relative price. By making the elasticity of demand depend upon the firm's relative sales, Kimball's preferences generate another kind of strategic complementarity that amplifies the effect of nominal disturbances and, everything else equal, reduces the size of the Phillips curve's slope.[10] Such property has spurred new research on various implications of the assumption of a non-constant elasticity of substitution. Dotsey and King (2005) use a specific functional form for the Kimball aggregator in a calibrated DSGE model to study the dynamic response of inflation and output to monetary shocks in the context of a state-dependent pricing model. Levin, Lopez-Salido and Yun (2006) adopt the Kimball specification to analyze the interaction of strategic complementarity and steady state inflation. In empirical work, Eichenbaum and Fisher (2007) use the same

[9] For example, with a Cobb-Douglas production technology $s_y = a/(1-a)$, where $1-a$ is the output elasticity with respect to labor.

[10] See the discussion of these preferences in the context of models with price rigidities in Woodford (2003).

specification to pin down a realistic estimate of the frequency of price re-optimization in the Calvo model. Finally, in the context of an open economy model, Gust et al. (2006) extend these preferences to the demand of home produced and imported goods, to show that with strategic complementarity lower trade costs reduce the pass-through of exchange rate movements to import prices.

Departing from the constant demand elasticity assumption along the lines of Kimball, the consumption aggregate in (2) is replaced by an aggregate C_t implicitly defined by

$$\int_{\Omega} \psi \left(\frac{c_t (i)}{C_t} \right) di = 1, \tag{10}$$

where $\psi(\centerdot)$ is an increasing, strictly concave function, and Ω is the set of all potential goods produced (a real line). With this notation the Dixit-Stiglitz aggregator corresponds to the case where $\psi(c_t(i)/C_t) = (c_t(i)/C_t)^{(\theta-1)/\theta}$ for some $\theta > 1$. With an aggregator function of the form (10) one can show[11] that the Calvo model implies an inflation dynamics of the baseline form, where the slope (again for simplicity, in the case of zero steady state inflation) becomes

$$\zeta = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha} \frac{1}{1+\overline{\theta}(\overline{s}_y + \overline{\epsilon}_\mu)}. \tag{11}$$

Here $\overline{\theta}$ is the steady state value of the firm's elasticity of demand, which is now a function $\theta(x)$ of the firm's relative sales (denoted by x); $\overline{\epsilon}_\mu$ is the steady state value of the function $\epsilon_\mu(x)$ that represents the elasticity of the mark-up function $\mu(x)$, which also depends on the firm's relative sales; $\overline{s}_y$ is the steady state value of the elasticity of the firm's marginal cost with respect to its own sales. The interactions of the new variables in the strategic complementarity term $\frac{1}{1+\overline{\theta}(\overline{s}_y+\overline{\epsilon}_\mu)}$ determines to what extent the slope ζ differs from that of the baseline case.

Expression (11) formalizes all the channels discussed in section 3 as those through which globalization may affect the strength of the relationship between inflation and marginal costs. It shows that the slope coefficient depends upon a number of variables: (i) the frequency of price revisions, represented by the coefficient α : less frequent price revisions (a higher value of α) correspond to lower ζ; (ii) the sensitivity of the desired firm's price to marginal cost versus other prices, the term $\overline{\epsilon}_\mu$: higher sensitivity reduces the slope; (iii) the sensitivity of marginal cost to the own output of the firm, the term $\overline{s}_y$; and (iv) the sensitivity of the firm's own output to the relative price, $\overline{\theta}$. In addition, the slope is possibly affected by the level of steady state inflation, which may interact with the demand elasticity, as in (8).

[11] See the later derivation for the specific parametrization considered.

The Calvo model enriched with these modifications is now a suitable framework for discussing the effects of globalization: the task is to relate the factors that drive the value of the slope to the increase in trade openness, that is one of the characteristics of a more global environment. This is what I consider next. Leaving aside the issue of whether globalization affects the frequency of price adjustments, and more generally the nominal rigidity term, in the next section I focus on the effects of an increase in trade on the strategic complementarity term.

5 The effect of firms' entry

5.1 Kimball preferences with a variable number of goods

I extend Kimball's (1995) model to an environment where the number of traded goods is variable. The model implies that the elasticity of demand depends on the firm's relative output share: by relating this share to the number of goods traded the steady-state elasticity of demand becomes function of the number of traded goods in steady state. This implies that the degree of strategic complementarity varies with the number of traded goods, hence so does the slope of the inflation-marginal cost curve.

I assume that households' utility is defined over an aggregate C_t of differentiated goods $c_t(i)$, defined implicitly by (10), where $\psi(\cdot)$ is an increasing, strictly concave function, and I also assume that $\psi(0) = 0$. If the set of goods that happen to be sold is $[0, N]$, then $c_t(i) = 0$ for all $i > N$, and C_t satisfies[12]

$$\int_0^N \psi\left(\frac{c_t(i)}{C_t}\right) di = 1. \tag{12}$$

The elasticity of demand, in this set-up, is defined as a function

$$\theta(x) = -\frac{\psi'(x)}{x\psi''(x)}, \tag{13}$$

where x indicates the relative market share of the differentiated goods. In Kimball's formulation the elasticity of demand is lower for those goods that sell more because their relative price is lower. Accordingly, the desired mark-up pricing over costs is as well a function of the market share:

$$\mu(x) = \frac{\theta(x)}{\theta(x) - 1}. \tag{14}$$

[12] Note that under this assumption changes in the number of goods available for sale involve no change in preferences as the utility function is independent of N. This contrast with Benassy's (1996) generalization of the Dixit-Stiglitz preferences, that depend on the value N.

The optimal consumption allocation across goods is the solution to the following problem:

$$\min_{\{c_t(i)\}} \int_0^N p_t(i)\, c_t(i)\, di \qquad \text{s.t.} \qquad \int_0^N \psi\left(\frac{c_t(i)}{C_t}\right) di = 1$$

The first order conditions for this problem are

$$p_t(i) = \frac{1}{\Lambda_t C_t} \psi'\left(\frac{c_t(i)}{C_t}\right) \tag{15}$$

for each $i \in [0, N]$, where Λ_t is the Lagrange multiplier for constraint (12). The solution to this minimization problem gives the demand for each good i as

$$c_t(i) = C_t \psi'^{-1}\left(p_t(i)\, \Lambda_t C_t\right), \tag{16}$$

where Λ_t is implicitly defined by the requirement that

$$\int_0^N \psi\left(\psi'^{-1}\left(p_t(i)\, \Lambda_t C_t\right)\right) di = 1. \tag{17}$$

Expression (17) defines a price index $\widetilde{P}_t \equiv \frac{1}{\Lambda_t C_t}$ for any set of prices $\{p_t(i)\}$, which is independent of C_t. We can then write the demand curve for good i as

$$y_t(i) = Y_t \psi'^{-1}\left(\frac{p_t(i)}{\widetilde{P}_t}\right). \tag{18}$$

Note that the aggregate 'price' $\widetilde{P}_t$ is not in general the same as the conventional price index, which here is defined, as in the case of Dixit-Stiglitz preferences, as the cost of a unit of the composite good, that is

$$P_t = \frac{1}{C_t} \int_0^N p_t(i)\, c_t(i)\, di = \int_0^N p_t(i)\, \psi'^{-1}\left(\frac{p_t(i)}{\widetilde{P}_t}\right) di, \tag{19}$$

where the second equality follows from (18). Both P_t and $\widetilde{P}_t$, however, are homogeneous of degree one functions in $\{p_t(i)\}$.

5.2 Steady state with symmetric prices

I am interested in the properties of the demand curve in a steady state with symmetric prices $p_t(i) = p_t$ for all i. In this case it follows from (12) that the relative demand $c_t(i)/C_t$ is equal to

$$c_t(i)/C_t = \psi^{-1}\left(\frac{1}{N}\right) \tag{20}$$

for all i, and from (15):

$$\widetilde{P}_t = \frac{p_t}{\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)}. \tag{21}$$

From the definition of P_t in (19) it also follows that

$$P_t = p_t\left[N\psi^{-1}\left(\frac{1}{N}\right)\right]. \tag{22}$$

The elasticity of demand in such a steady state, denoted by $\overline{\theta}$, is

$$\overline{\theta} = -\frac{\psi'(x)}{x\psi''(x)}, \tag{23}$$

where $x = \psi^{-1}\left(\frac{1}{N}\right)$ denotes the relative share in the symmetric steady state. Note how this elasticity differs from the case of the Dixit-Stiglitz aggregator, where the elasticity of demand is a constant $\theta(x) = \theta$ for all x. Here the demand elasticity depends upon the relative market share of the good, and its value in steady state, $\overline{\theta}$, is a function of the number of goods traded in steady state, N. I am interested in seeing *how* this steady state elasticity $\overline{\theta}$ varies with N. The extent of this variation depends on how the elasticity function $\theta(x)$ varies with x.[13]

The assumptions made so far do not have implications for the sign of $\theta'(x)$. However, if we assume, as Kimball (1995) does, that the function $\theta(x)$ is decreasing in x, then, since $\psi^{-1}\left(\frac{1}{N}\right)$ is decreasing in N, it follows that $\overline{\theta}$ is *increasing* in N. This is in line with the general intuition that more goods are traded in a market, more likely it is for the demand to decrease more in response to a small increase in prices.

As $\overline{\theta}$ varies with the number of goods traded, so does the desired mark-up of prices over costs, evaluated in steady state. I define the steady state desired mark-up as $\overline{\mu} \equiv \frac{\overline{\theta}}{\overline{\theta}-1}$: if $\overline{\theta}$ is increasing in N, then the steady state desired mark-up is decreasing in N. For what it is discussed later on it is also important to evaluate the extent to which the mark-up itself, as defined in (14), varies with the relative sales, and therefore with the number of traded goods.

The elasticity of the mark-up function is defined as

$$\epsilon_\mu(x) = \frac{\partial \log \mu(x)}{\partial \log x} = \frac{x\mu'(x)}{\mu(x)} \tag{24}$$

[13]The function $\theta(\centerdot)$ could also be expressed as a function of the relative price, rather than the market share, as in Gust et al. (2006).

which, evaluated at $x = \psi^{-1}\left(\frac{1}{N}\right)$, is denoted as[14]

$$\overline{\epsilon}_\mu = \frac{x\mu'(x)}{\mu(x)}. \tag{25}$$

The elasticity $\overline{\epsilon}_\mu$ determines how much $\overline{\mu}$ varies for a small variation in N.[15] Since

$$\frac{\partial \log \mu}{\partial \log N} = \frac{\partial \log \mu}{\partial \log x} \cdot \frac{\partial \log x}{\partial \log N} = \overline{\epsilon}_\mu \cdot \frac{\partial \log x}{\partial \log N}$$

and, since $\frac{1}{N} = \psi(x)$,

$$\frac{\partial \log N}{\partial \log x} = -\frac{x\psi'(x)}{\psi(x)} = -N\psi^{-1}\left(\frac{1}{N}\right)\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right),$$

we have that

$$\frac{\partial \log \mu}{\partial \log N} = \frac{-\overline{\epsilon}_\mu}{N\psi^{-1}\left(\frac{1}{N}\right)\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)}.$$

The elasticity of μ with respect to N has therefore the opposite sign of the elasticity $\overline{\epsilon}_\mu$. In turn we can determine how $\overline{\epsilon}_\mu$ must vary with N by considering how $\epsilon_\mu(x)$ varies with x. Since we can argue that $\log \mu$ is a convex function of $\log x$,[16] it follows from definition (24) that $\epsilon_\mu(x)$ is an increasing function of x : we can then conclude that $\overline{\epsilon}_\mu$ is a *decreasing* function of N .

Finally, it can be shown that the steady state sensitivity of the firm's marginal cost to its own output, $\overline{s}_y$, is also a function of N. This elasticity depends upon assumptions about the form of the production function and about consumer preferences, which I haven't spelled out yet. I make here some simplifying assumptions to illustrate the nature of the dependence of $\overline{s}_y$ on N. Let the production function of firm i be

$$y_t(i) = h_t(i)^{1-a} - \Phi \tag{26}$$

[14]Note that this elasticity could alternatively defined as $\epsilon_\mu(x) = -\epsilon_\theta(x)/[\theta(x) - 1]$, where $\epsilon_\theta(x) = \frac{\partial \log \theta(x)}{\partial \log x}$.

[15]The value of $\overline{\epsilon}_\mu$ is important to determine the degree of strategic complementarities in price setting, for small departures from the uniform-price steady state (see Woodford 2003).

[16]This follows from the hypothesis that $\theta'(x) < 0$, so that $\mu(x)$ is an increasing function of x. In this case it is not possible for $\log \mu$ to be a concave function of $\log x$, because this would require $\log \mu$ to be negative for positive, and small enough x. But this can't happen, no matter how large $\theta(x)$ gets for small x. If $\log \mu$ must be convex at least for small values of x, it is convenient to assume that it is a globally convex function of $\log x$.

where Φ is a fixed cost. This leads to a labor demand function

$$h_t(i) = (y_t(i) + \Phi)^{\frac{1}{1-a}} \tag{27}$$

Assuming an economy -wide labor market, with nominal wage W_t, the total cost of production of firm i is $W_t h_t(i)$, and its real marginal cost is

$$s_t(i) = \frac{MC_t}{P_t}(y_t(i); \Gamma_t) = \frac{1}{1-a}\frac{W_t}{P_t}(y_t(i) + \Phi)^{\frac{a}{1-a}}. \tag{28}$$

where Γ_t indicates aggregate variables that enter into the determination of firms' marginal costs. The elasticity of the marginal cost to firm's own output is then

$$s_y(y_t(i); \Gamma_t) = \frac{a}{1-a}\left[\frac{y_t(i)}{y_t(i) + \Phi}\right]$$

which, evaluated at a steady state with symmetric prices, is

$$\overline{s}_y = \frac{a}{1-a}\left[\frac{xY}{xY + \Phi}\right] = \frac{a}{1-a}\left[\frac{x}{x + \Phi/Y}\right]. \tag{29}$$

where again $x = \psi^{-1}(1/N)$ and I denoted the steady state of aggregate output by Y. Since both x and Y are functions of N, so is $\overline{s}_y$: whether it increases or decreases with N depends upon whether x or $1/Y$ decreases more sharply with N. I discuss this point with some detail in the appendix.

We have thus established that the steady state elasticity of demand $\overline{\theta}$ is *increasing* in N, while the elasticity of the desired mark-up evaluated in steady state $\overline{\epsilon}_\mu$ is *decreasing* in N; how the elasticity of the marginal cost to firm's own output $\overline{s}_y$ depends on N is established numerically in the quantitative exercise. The overall role of N in the price/marginal cost relationship is examined next.

5.3 The price setting problem

The firms pricing problem in this set up generalizes the one considered in section 4. Price setting firms at t choose their price $p_t(i)$ to maximize the following expected string of profits over the life of the set price:

$$E_t\left\{\sum_{j=0}^{\infty}\alpha^j Q_{t,t+j}\left[p_t(i)Y_{t+j}\ \psi'^{-1}\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right) - \mathsf{C}\left(Y_{t+j}\ \psi'^{-1}\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right); \Gamma_{t+j}\right)\right]\right\}$$

where $\mathsf{C}(.)$ is the firm's cost function; generalizing (4), the FOC for this problem are

$$E_t \sum_{j=0}^{\infty} \left(\begin{array}{c} \alpha^j Q_{t,t+j} P_{t+j} Y_{t+j} \; x\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right) \left[\theta\left(x\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right)\right) - 1\right] \times \\ \left[\frac{p_t(i)}{P_{t+j}} - \mu\left(x\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right)\right) \; s\left(Y_{t+j} \; \psi'^{-1}\left(\frac{p_t(i)}{\widetilde{P}_{t+j}}\right); \Gamma_{t+j}\right)\right] \end{array} \right) = 0$$

where the relative share is $x\left(\frac{p}{\widetilde{P}}\right) \equiv \psi'^{-1}\left(\frac{p}{\widetilde{P}}\right)$. The functions $\theta(x)$ and $\mu(x)$ are the functions defined in (13) and (14), and $s(y_t(i); \Gamma_t)$ is the real marginal cost of producing quantity $y_t(i)$ in period t, given aggregate state Γ_t, which is unaffected by the pricing decision of firm i.[17]

Log-linearizing the FOC around a steady state with zero inflation one obtains:

$$E_t \sum_{j=0}^{\infty} (\alpha\beta)^j \left[\begin{array}{c} \left(\widehat{p}_t^* - \Sigma_{k=1}^{j} \pi_{t+k}\right) + \overline{\epsilon}_\mu \overline{\theta}\left(\widehat{p}_t^* - \Sigma_{k=1}^{j} \widetilde{\pi}_{t+k} + \log\left(\frac{P_t}{\widetilde{P}_t}\right) - K\right) + \\ \overline{s}_y \overline{\theta}\left(\widehat{p}_t^* - \Sigma_{k=1}^{j} \widetilde{\pi}_{t+k} + \log\left(\frac{P_t}{\widetilde{P}_t}\right) - K\right) - \widehat{s}_{t+j} \end{array} \right] = 0 \qquad (30)$$

where $\widehat{p}_t^* = \log\left(\frac{p_t^*}{P_t}\right) - \log\left(\frac{p}{P}\right)|_{ss}$; $\pi_t \equiv \Delta \log P_t$, $\widetilde{\pi}_t \equiv \Delta \log \widetilde{P}_t$; $K \equiv \log\left(\frac{P}{\widetilde{P}}\right)|_{ss}$; $\overline{s}_y = \frac{\partial \log s_t(i)}{\partial \log y_t(i)}|_{ss}$, $\widehat{s}_t = \log s(Y_t; \Gamma_t) - \log s(Y; \Gamma)|_{ss}$, and the steady state values follow from previous calculations. In particular, from (22)

$$\log\left(\frac{p^*}{P}\right)|_{ss} = -\log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right];$$

from (22) and (21)

$$\log\left(\frac{P}{\widetilde{P}}\right)|_{ss} = \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)\right]$$

and, since $\log s_t \equiv \log\left(\frac{MC}{p}\frac{p}{P}\right)$ it follows that:

$$\log s(Y; \Gamma)|_{ss} = -\log \overline{\mu} - \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right]. \qquad (31)$$

Log-linearizing the dynamics of the price indices, one gets, for $\widetilde{P}_t$

$$\int_0^N \left(\log p_t(i) - \log \widetilde{P}_t - \log\left[\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)\right]\right) di = 0$$

which, to a first order approximation, gives

$$\log \widetilde{P}_t = \frac{1}{N}\int_0^N \log p_t(i)\, di - \log\left[\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)\right].$$

[17] Note that the real marginal cost is defined as the ratio $MC_t(i)/P_t$, not the ratio $MC_t(i)/\widetilde{P}_t$.

For P_t, as defined in (19), we have

$$\int_0^N \left\{ \log p_t(i) - \log P_t + \log \left[N\psi^{-1}\left(\frac{1}{N}\right)\right] + \frac{\psi'(x)}{x\psi''(x)} \left(\log p_t(i) - \log \widetilde{P}_t - \log\left(\frac{p(i)}{\widetilde{P}}\right)|_{ss}\right)\right\} di = 0$$

which, to a first order approximation, implies

$$\log P_t = \frac{1}{N}\int_0^N \log p_t(i)\, di + \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right]. \tag{32}$$

Therefore, to a first order approximation,

$$\log\left(P_t/\widetilde{P}_t\right) = \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right] + \log\left[\psi'\left(\psi^{-1}\left(\frac{1}{N}\right)\right)\right] \equiv K$$

and therefore

$$\widetilde{\pi}_t = \pi_t.$$

Under the assumption of Calvo staggered prices, we can also write the expression for the general price level (32) as

$$\begin{aligned}
\log P_t &= \frac{1}{N}\left(\alpha\int_0^N \log p_{t-1}(i)\, di\right) + (1-\alpha)\log p_t^* + \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right] \\
&= \alpha \log P_{t-1} + (1-\alpha)\left(\log p_t^* + \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right]\right) \\
&= \alpha\log P_{t-1} + (1-\alpha)\left(\widehat{p}_t^* + \log P_t\right)
\end{aligned}$$

where the last equality follows from the definition of $\widehat{p}_t^*$. We then have

$$\alpha \log P_t = \alpha \log P_{t-1} + (1-\alpha)\,\widehat{p}_t^*. \tag{33}$$

5.4 The slope of the NKPC

The log-linearized equilibrium conditions (30) and (33) can now be expressed, respectively, as

$$E_t \sum_{j=0}^{\infty} (\alpha\beta)^j \left[\left(1 + \overline{\theta}\left(\overline{\epsilon}_\mu + \overline{s}_y\right)\left(\widehat{p}_t^* - \sum\nolimits_{k=1}^{j} \pi_{t+k}\right) - \widehat{s}_{t+j}\right)\right] = 0 \tag{34}$$

and

$$\pi_t = \frac{1-\alpha}{\alpha}\,\widehat{p}_t^*. \tag{35}$$

With typical transformations, (34) and (35) imply again an expression for inflation of the form

$$\pi_t = \zeta \widehat{s}_t + \beta E_t \pi_{t+1}$$

where, however, the slope is now defined as in (11), and more explicitly as

$$\zeta = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha} \frac{1}{1+\overline{\theta}(N)\left[\overline{\epsilon}_{\mu}(N)+\overline{s}_{y}(N)\right]}. \tag{36}$$

Through the terms $\overline{\epsilon}_{\mu}$, $\overline{s}_y$ and $\overline{\theta}$ the slope ζ depends upon the number of goods traded in steady state.[18] As we discussed, $\overline{\theta}$ is increasing in N while $\overline{\epsilon}_{\mu}$ is decreasing in N, and the elasticity $\overline{s}_y$ will be shown to be as well decreasing in N. The net effect of a change in the steady state value of traded goods on the slope depends on the relative size of the changes in all these variables. This is what I analyze next.

6 Quantitative effect of trade increase on the PC slope

In order to evaluate the quantitative impact of the trade increase on the slope ζ, I need to parametrize the function $\psi(x)$. First, I choose a functional form along the lines of Dotsey and King (2005), setting:

$$\psi(x) = \frac{1}{(1+\eta)\gamma}\left[(1+\eta)x-\eta\right]^{\gamma} - \frac{1}{(1+\eta)\gamma}(-\eta)^{\gamma},$$

where the constant term is chosen to satisfy the condition $\psi(0)=0$ stated above.

For this form of $\psi(x)$ the demand function (16) is derived as

$$\frac{c_t(i)}{C_t} = \frac{1}{1+\eta}\left[\left(\frac{p_t(i)}{\widetilde{P}_t}\right)^{\frac{1}{\gamma-1}}+\eta\right],$$

which is a sum of a constant and a Dixit-Stiglitz term, and where the parameters γ and η control the elasticity and the curvature of the function. I discuss later the choice of particular values for the parameters γ and η that I use for the quantitative exercise.

Using the derivations of the previous section, I can now write explicit expressions for the variables that enter the slope of the Phillips curve that show how they depend on N in a steady state with symmetric prices. The steady state relative share x in (20) is

$$x \equiv \psi^{-1}\left(\frac{1}{N}\right) = \frac{1}{1+\eta}\left\{\left(\frac{(1+\eta)\gamma}{N}+(-\eta)^{\gamma}\right)^{\frac{1}{\gamma}}+\eta\right\}; \tag{37}$$

---

[18] It should also be observed that N has an additional effect on the inflation dynamics that can be seen by rewriting (6) as

$$\pi_t = \zeta\left(\log s_t - \log\overline{s}\right) + \beta E_t \pi_{t+1}.$$

The steady state value of the marginal cost is function of the steady state mark-up $\overline{\mu}$ and the steady state relative price p/P, both functions of N: $\log\overline{s}(N) = -\log\overline{\mu}(N) - \log\left[N\psi^{-1}\left(\frac{1}{N}\right)\right]$.

the steady state elasticity (23) is

$$\overline{\theta} = \frac{\eta - (1+\eta)\psi^{-1}(1/N)}{(\gamma-1)(1+\eta)\,\psi^{-1}(1/N)}, \tag{38}$$

and the elasticity of mark-up (25) is the following function of N:

$$\overline{\epsilon}_{\mu} = \frac{\eta\,(\gamma-1)(1+\eta)\,\psi^{-1}(1/N)}{\left(\eta - (1+\eta)\psi^{-1}(1/N)\right)\left(\eta - \gamma(1+\eta)\psi^{-1}(1/N)\right)}.$$

Finally, the steady state mark-up is

$$\overline{\mu} = \frac{\eta - (1+\eta)\psi^{-1}(1/N)}{\eta - \gamma(1+\eta)\psi^{-1}(1/N)}.$$

By calibrating values for the parameters η and γ, we can evaluate the quantitative effect of an increase in N on the slope of the inflation - marginal cost function.

Unfortunately the literature doesn't offer much guidance for what are the most plausible values for η and γ. One possibility is to choose a combination of these two parameters that guarantees a desired value for the mark-up (hence for the demand elasticity) in a steady state where the relative share x is equal to 1. Dotsey and King (2005), for example, set $\gamma = 1.02$, and determine η so that $\overline{\theta}(1) = 10$ (or a mark up of 11%), which gives $\eta = -6$.[19] Levin et al. (2006), in order to have a markup of 16% in their baseline case, choose instead a lower value for the demand elasticity at 1, setting $\overline{\theta}(1) = 7$, and set $\eta = -2$. In an open economy model Gust et al. (2006) choose η to match their model's implications for the volatility of output, and then select γ to give a 20% markup pricing in steady state (and $\overline{\theta}(1) = 6$). This implies setting $\gamma = 1.15$ and $\eta = -1.87$. The larger is η in absolute value, the more concave is the demand function. This is shown in figure 1 for the case in which $\overline{\theta}(1) = 7$, and in figure 2 for the case of $\overline{\theta}(1) = 10$. The red line with circles in each figure corresponds to $\eta = 0$, which is the Dixit-Stiglitz constant elasticity case.

I will start by considering the implications of the parametrization of Levin et al. (2006), and then evaluate the case of a lower initial mark-up, as assumed in the parametrization of Dotsey and King. Both these parametrizations assume an elasticity at the point of unit market share relatively in line with constant elasticity estimates obtained from macro data.[20]

[19] It follows from (23) that for $x = 1$: $\overline{\theta} = \frac{-1}{(\gamma-1)(1+\eta)}$.

[20] At the macro level, Cogley-Sbordone (2005) estimate a Calvo model with a Dixit-Stiglitz specification and time-varying inflation trend; they estimate the Dixit-Stiglitz elasticity using aggregate data on inflation, unit labor costs, output and interest rates across subperiods (chosen a priori as representing periods of different steady state inflation). They do not find evidence that the elasticity differs across the subsamples, which cover pre and post 1990, and estimate an elasticity of about 10.

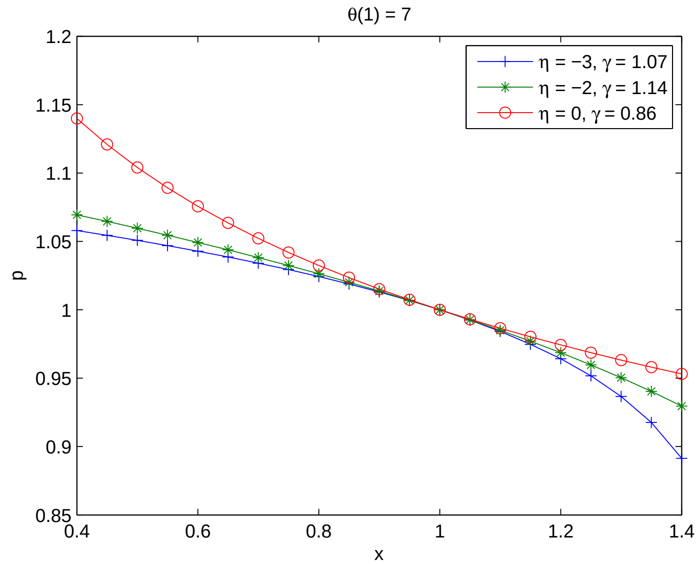

Figure 1: Demand functions for various parametrizations; $\overline{\theta}(x) = 7$ at $x = 1$.

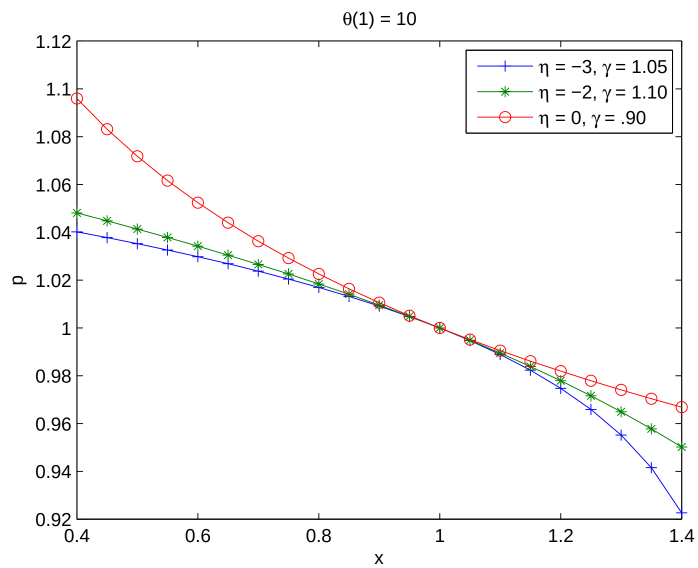

Figure 2: Demand functions for various parametrizations; $\overline{\theta}\,(x) = 10$ at $x = 1$.

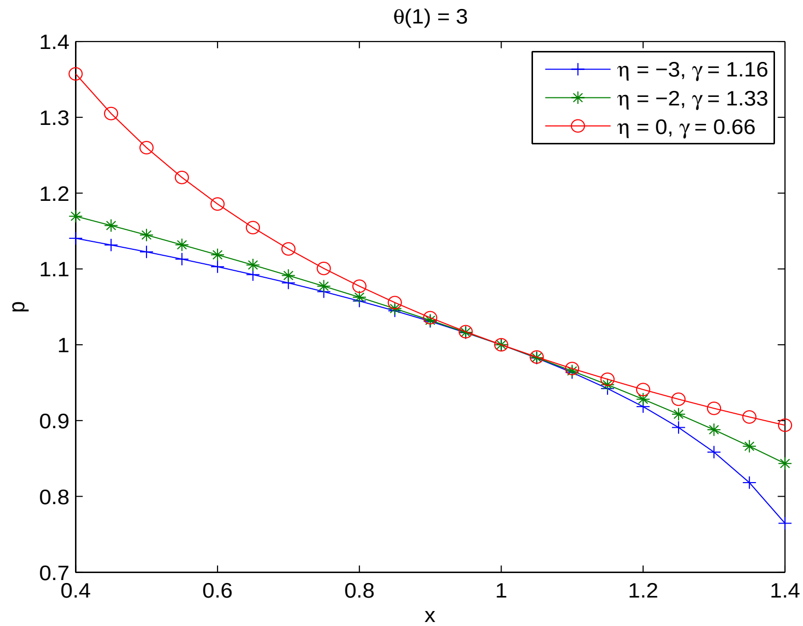

Figure 3: Demand functions for various parametrizations; $\overline{\theta}(x) = 3$ at $x = 1$.

With micro data, however, the estimate of the elasticity of substitution depends on the level of aggregation. Broda and Weinstein (2006), for example, estimate elasticities for a larger number of goods at three different levels of aggregation, and found higher elasticities for more disaggregated sectors, showing that varieties are more close substitute when disaggregation is higher. Although their estimated elasticities cover a wide range of values, the median elasticities for the period 1972-88 range from 2.5 to 3.7, depending on the aggregation level.[21] This suggests to investigate as well the effects of parametrizations based on the assumption of a much lower elasticity in the initial steady state: by identifying this state with the period 1972-1988, which represents a pre-globalization period, I consider the case of $\overline{\theta}(1) = 3$. Figure 3 shows the demand functions for this case, in a manner analogous to figures 1 and 2.

As for the choice of the two parameters η and γ, for each of the assumed initial values of $\overline{\theta}$, I choose two alternative values for η, -3 and -2, as reported in the figures: more negative values would make the demand curve too kinked. Given η, a value for γ follows

[21] It's also interesting to note that their estimated elasticities, across each disaggregation group, rather than increase, appear to decrease, albeit slightly, in the 1990-2001 period versus the 1972-1988. Their interpretation is that imported goods have become more differentiated over time.

from expression (23) evaluated at $x = 1$.

Figure 4 shows the various components of the 'strategic complementarity' term of the slope and the slope itself, for a given nominal rigidity component,[22] adopting the parametrization of Levin et al. (2006).[23] The graph on the top-left corner shows the market share as function of traded goods, $x = \psi^{-1}(1/N)$); the following graphs show the steady state demand elasticity $\overline{\theta}$, the mark up $\overline{\mu}$, the markup elasticity $\overline{\epsilon}_\mu$, the elasticity of the marginal cost to output $\overline{s}_y$, and the Phillips curve slope ζ, all as functions of the number of traded goods N, which is on the horizontal axis (the functions are all evaluated at $x = \psi^{-1}(1/N)$). The curves with crosses depict the case of a more concave demand ($\eta = -3$, and $\gamma = 1.07$); the starred curves correspond to a less concave demand function ($\eta = -2$, and $\gamma = 1.14$). Note how the decline in the desired mark-up is consistent with the evidence that an increase in trade is making the economy more competitive, as documented for example by Chen, Imbs and Scott (2006) for European countries.

The behavior of the real rigidity component of the slope depends on how the two products $\overline{\theta}\overline{\epsilon}_\mu$ and $\overline{s}_y\overline{\theta}$, which are on the denominator of expression (36), vary with the number of traded goods N. For both the chosen parametrizations in the figure, the demand elasticity $\overline{\theta}$ (graph on the top right corner) increases almost linearly in N, and the elasticity $\overline{s}_y$ (graph on the bottom left of the figure) decreases almost linearly in N. The mark-up elasticity $\overline{\epsilon}_\mu$ is a convex function of N, which declines quite rapidly as N increases from low values in the case of a more concave demand function (the blue curves with crosses). This sharp decline in $\overline{\epsilon}_\mu$ causes a decline in the product $\overline{\theta}\overline{\epsilon}_\mu$ which, at low values of N, dominates the increase in the term $\overline{s}_y\overline{\theta}$ determining a moderate increase in the slope for these values. In the case of a less concave function, as the green lines with stars show, the two terms $\overline{\theta}\overline{\epsilon}_\mu$ and $\overline{s}_y\overline{\theta}$ offset one another, so that at low values of N the slope curve is essentially unchanged, and then it declines monotonically. For large enough values of N, however, the slope declines regardless of the concavity of the demand function.

To evaluate how sensitive this outcome is to different specifications of the parameters of the aggregator function, the next two figures plot the behavior of the same variables for the two alternative parametrizations discussed: one obtained by imposing that the parameters deliver a lower mark-up in the steady state with unit market share (the Dotsey-King case),

[22] Recall that this term is defined as $\frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$ and doesn't depend on N. I calibrate $\beta = .99$ and $\alpha = .7$, which corresponds to an average interval of 9-10 months between price changes.

[23] That is, the combinations of the parameters η and γ are such that the demand elasticity in a steady state with unit market share is equal to 7.

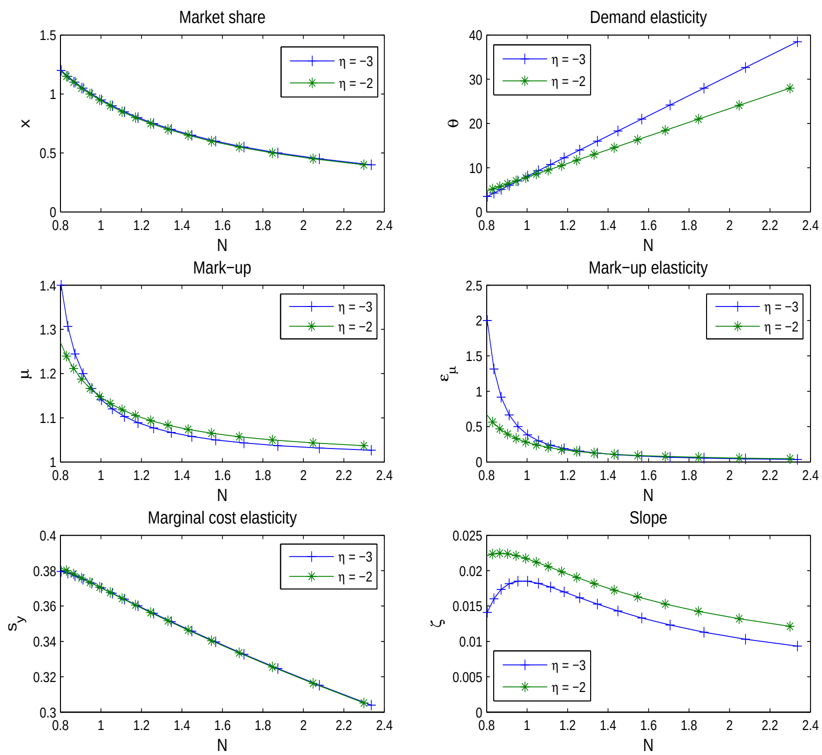

Figure 4: Parametrizations: $\eta = -2, \gamma = 1.14$, and $\eta = -3, \gamma = 1.07$

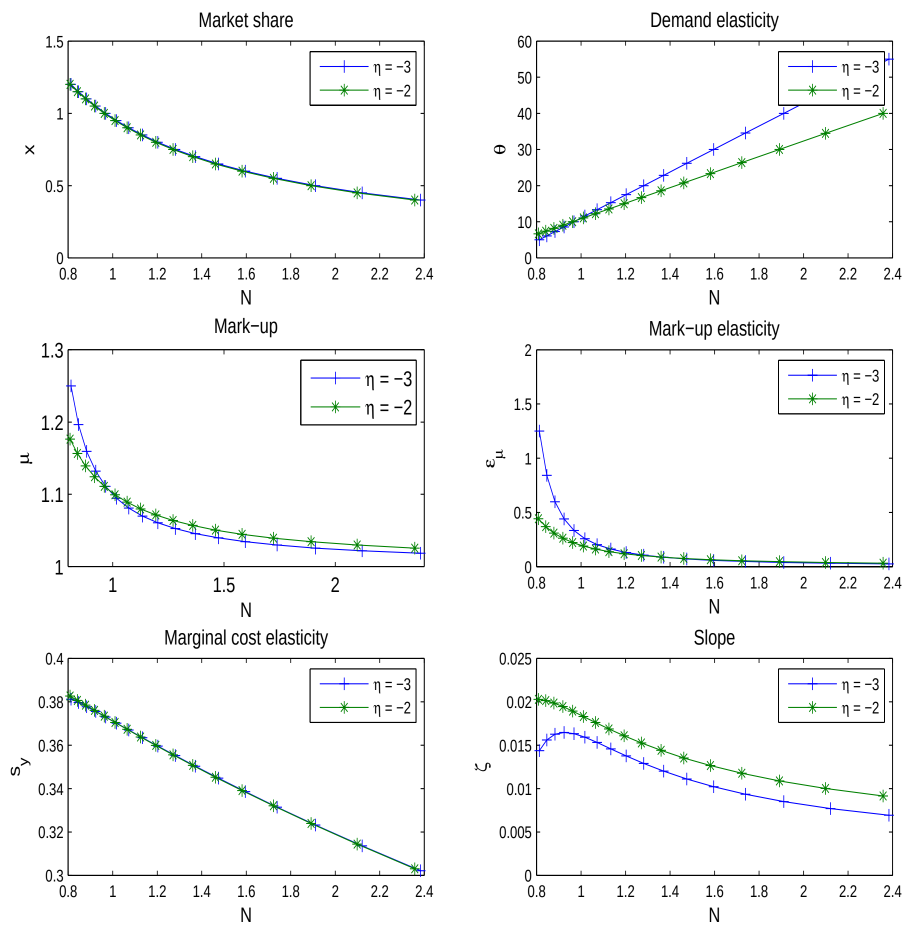

Figure 5: Parametrizations: $\eta = -2, \gamma = 1.10$, and $\eta = -3, \gamma = 1.05$.

the other where the initial steady state mark-up is very high (the case of Broda-Weinstein). The specific calibrations of the parameters η and γ are indicated in each figure.

Figure 5 plots the same variables as in figure 4 for a combination of parameters η and γ that deliver a demand elasticity $\overline{\theta} = 10$ at $x = 1$. As the figure shows, this case is relatively similar to the previous one, except that the term $\overline{\theta}\overline{\epsilon}_\mu$ has a weaker effects of the slope, reducing the extent to which the slope increases when N increases near the low initial level.

Larger differences can instead be observed for the case where the aggregator function is parametrized to deliver a smaller elasticity in the steady state with unit market share $\left(\overline{\theta}\left(1\right) = 3\right)$. This case is reported in figure 6.

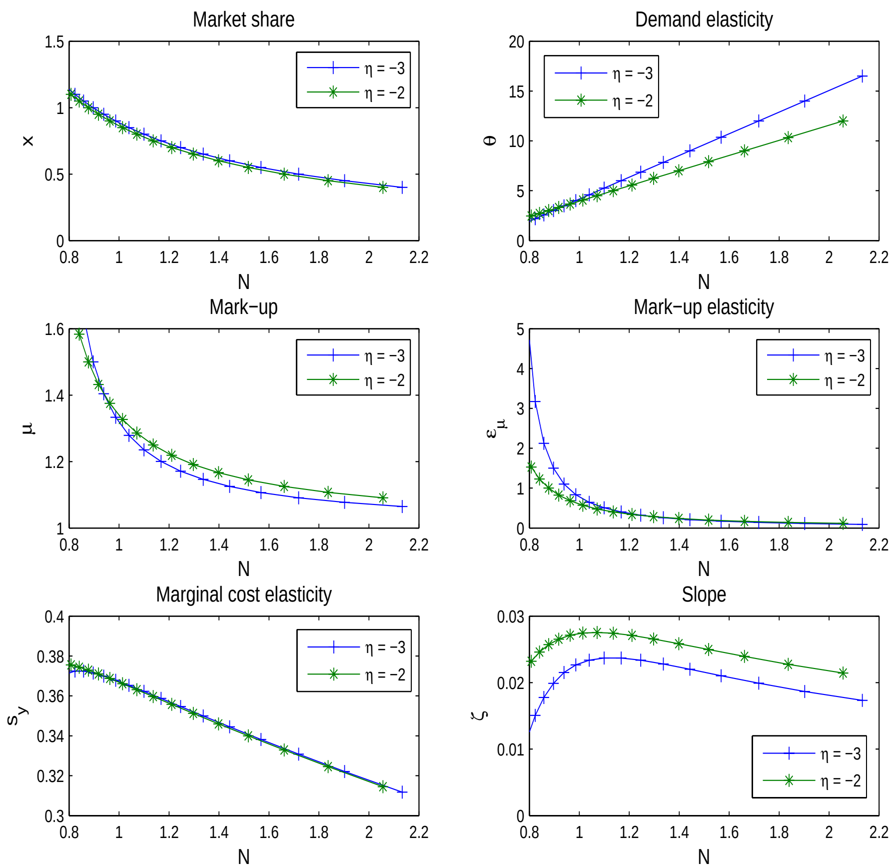

Figure 6: Parametrizations: $\eta = -2, \gamma = 1.33$, and $\eta = -3, \gamma = 1.16$.

The figure shows that the elasticity of demand increases at a slower rate with the increase in N, and the mark-up elasticity, which is very high at the initial steady state, declines very sharply when N increases: this decline makes the term $\overline{\theta}\overline{\epsilon}_{\mu}$ dominate once again the behavior of the slope. As the graph on the bottom right shows, in this case the slope increases for a larger range of values of N for both parametrizations, and more markedly so the more concave is the demand function. Also, as N grows the slope eventually declines but, for the range of values considered in the figure, it remains always above its initial value.

6.1 Measuring the trade increase

The previous figures illustrate how moving from a steady state with low N to a steady state with high N has a potential effect on the slope of the NK Phillips curve. However, the assessment of the magnitude of the change in the slope is sensitive to the parametrization of the demand curve. And, within each parametrization, it matters how big is the level of traded goods that characterizes the new steady state, because of the non monotonicity of the slope function ζ. Hence, in order to make a quantitative assessment of the impact of the increase in market competition on the new Keynesian Phillips curve trade-off, one has to measure the size of the increase in trade associated with the globalization of the '90 in a way appropriate to represent the variable N of the model.

US goods imports have significantly increased in the 1960-2006 period. Figure 7 shows that the share of goods imports on GDP went from a little more than 4 percent in 1960 to about 22 percent by the end of 2006, with an increase from about 12 to 22 percent since 1989. For this latest period, however, the increase in import share excluding oil products is more modest going from about 8 to 12 percent.

The model however associates the increase in competition with an increase in the number of goods traded in the economy. For this purpose a more appropriate measure is provided by the number of varieties, as reported in the study by Broda and Weinstein (2006), which addresses the issue of the effect of globalization on trade.

Broda and Weinstein study the period 1972-2001, which they divide in two sub-periods, 1972-1988 and 1990-2001, and for each of them they report the number of varieties traded.[24] From 1990 to 2001 they register an increase in the total varieties of goods available to consumers of about 42% : the number of varieties went from approximately 182,000 to about 259,000 (table I of the paper). They observe, though, that a large number of varieties have a very small market share: to correct for a possible bias, they also provide a measure of value-weighted varieties. Under this measure, the increase in varieties is much smaller, of the order of 5 percent.[25] In the quantitative exercise I conduct below I take these two numbers as rough measures of the increase in the number of goods N to evaluate the effect of such

[24] They define a variety as "import of a particular good from a particular country" (p. 550) and use two different sources for each subperiod (data on 1989 are not included because of the unification of Germany in that year, which makes the data not comparable with those of the following years).

[25] This is obtained from the reported λ ratio in table VII of Broda-Weinstein (2006). The gross increase in varieties is computed as the inverse of the (median) λ ratio reported for the corrected count and for the one in table I.

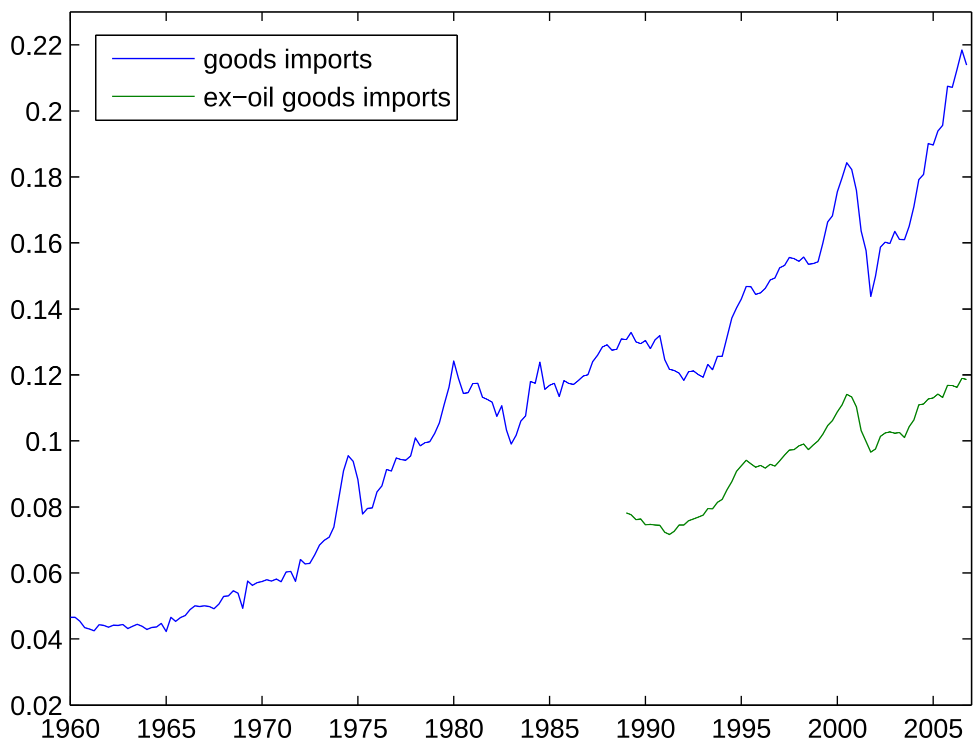

Figure 7: Goods Imports / GDP ratios, 1960 - 2006

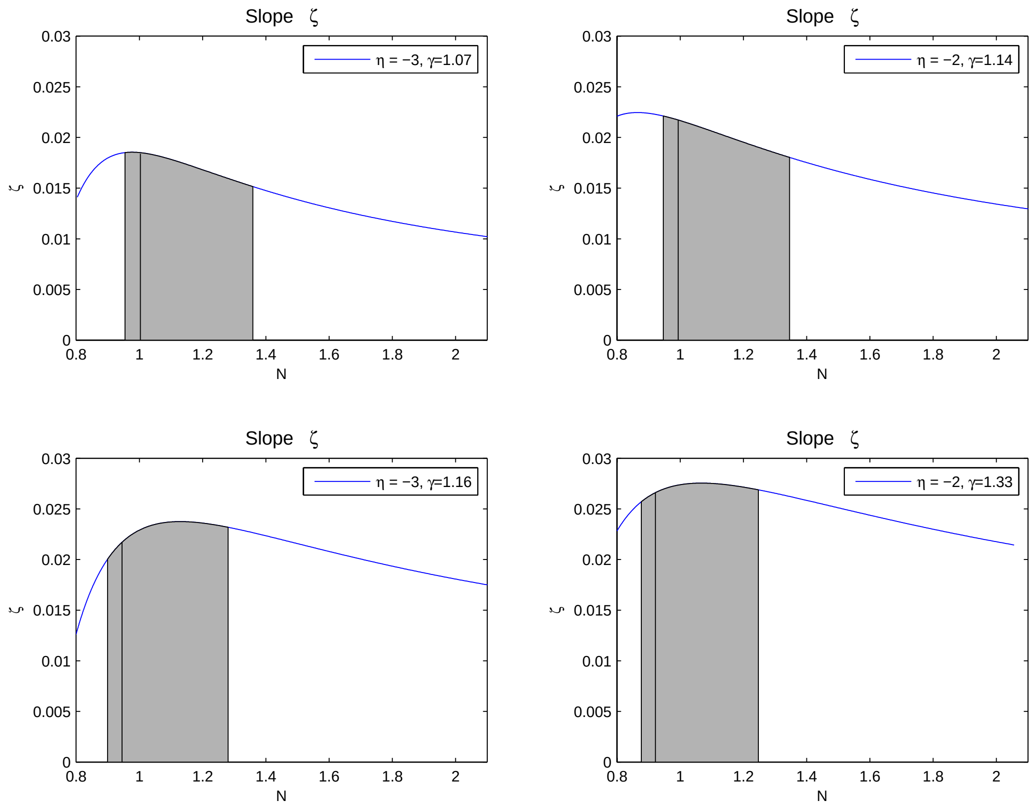

Figure 8: Effect of N on the slope ζ

increases on the degree of competitiveness and on the slope of the Phillips curve.

The first row of figure 8 reproduces the slope obtained under the two parametrizations of the aggregator function reported in figure 4. Consider first the case of $\eta = -3$ (the graph on the left): if we characterize the initial steady state as one where the relative share is $x = 1$, then in this steady state the number of goods traded is approximately $N = 1/\psi(x) = .96$, while by construction the elasticity of demand at that point is $\overline{\theta} = 7$. As discussed, the increase in the quantity of traded goods documented by Broda and Weinstein (2006) is of the order of 5 percent in terms of the value-weighted measure, but of about 42 percent without the weight. The shaded area between the first two vertical lines (from left to right) indicates the effect of moving from the initial steady state to a new steady state with a number of traded goods 5 percent higher. The vertical line farther to the right indicates a new steady state where the number of traded goods is instead 42 higher than the initial value. As the graph shows, a 5 percent increase in N is too small a change to affect the size of the slope: the decline in the product $\overline{\theta}\overline{\epsilon}_{\mu}$ is almost entirely offset by the increase in the term $\overline{s}_y\overline{\theta}$, so that the slope is essentially unchanged for these low values of N ($\zeta = .0185$). A 42 percent increase, on the other hand, generates an overall increase in the term $(\overline{\epsilon}_\mu + \overline{s}_y)\,\overline{\theta}$ (the decline in the component $\overline{\theta}\overline{\epsilon}_\mu$ is more than offset by the increase in $\overline{s}_y\overline{\theta}$) so that the slope declines from about 0.0185 to 0.015. In the case of a less concave demand function (graph on the upper right) even a small increase in the steady state value of N has the effect of lowering the value of the slope. In this case, in fact, the increase in the component $\overline{s}_y\overline{\theta}$ dominates the 'real rigidity' component of the slope, making ζ smaller for any value of N larger than the initial value (the maximum decline of the slope is from 0.022 to 0.0181).

The quantitative assessment that emerges from the second row of figure 8 is quite different. Here I report how the PC slope varies with N in the two parametrizations considered in figure 6, which, relative to the previous case, start from a lower steady state elasticity ($\overline{\theta}\,(1) = 3$). As in the row above, the slope in the left graph is obtained from a parametrization which corresponds to a more concave demand function, relative to the one on the right. In both cases, as we observed from the discussion in the previous section, the slope tends to raise with N for a large range of values. In the initial steady state the slope is about 0.019; in a steady state where N is only 5 percent higher, the slope raises to 0.021, and in a steady state where N is almost twice as high the slope would be 0.023. The result is very similar in the case of a less concave demand function (graph on the bottom right of the figure), although the size of the slope in this case is higher for all values of N.

Overall, according to the model presented, it would be difficult to argue that the increase in trade observed in the '90s in the US should have generated an increase in competition that could lead to a decline in the slope of the inflation/ marginal cost relation. It is indeed quite possible that the increased competition has instead resulted in an increase in the slope. Moreover, this conclusion is obtained without allowing for any increase in the frequency of price adjustment in a more competitive environment, of the kind hypothesized by Rogoff (2003). Note, however, that since one is comparing two different steady states, the results depend very critically on the curvature of the demand function in the initial steady state, and on how far the new steady state is from the initial one.

7 Conclusion

In this paper I discuss whether globalization, by generating an increase in market competition, has the potential of reducing the inflation output trade-off, namely whether it is responsible for the flattening the Phillips curve that many empirical analyses suggest occurred in the past twenty years or so.

I use the Calvo model of inflation dynamics to disentangle the components of this trade-off, and focus on the relationship between inflation and marginal costs. To analyze how this relationship, which I call the relevant 'slope', is affected by trade and market competition I depart from the model's traditional assumption of a constant elasticity of demand, making this elasticity depend instead on the relative market share of the differentiated goods. When trade moves the economy from a steady state with low trade to one with higher trade, the elasticity of demand facing the firms increases, but the elasticity of the desired mark-up declines. The balance of these two forces is the key element determining how the degree of strategic complementarity, and with it the inflation-marginal costs component of the Phillips curve slope, vary.

I argue that it is not clear that the trade increase observed in the globalization period is strong enough to have generated a decline in this component of the slope. When marginal cost is related to output, there is a further effect of the trade increase on the overall slope, since in the model the elasticity of marginal cost to aggregate output comprises the elasticity $\overline{s}_y$ which is indeed a decreasing function of number of traded goods. This effect is, however, quantitatively small, as the figures show.

A proper analysis of all the effects of a more integrated economy on the inflation-output trade-off would require to move more clearly to an open-economy setup, which would allow one to account for the price dynamics of goods produced abroad and consumed, as final or intermediate goods, in the domestic economy. As it has been shown (see for example Razin and Yuen 2002) the open economy Phillips curve is flatter than the curve of a closed economy, even in the presence of a constant elasticity of marginal cost to output, because the overall slope is declining in a trade openness parameter. My analysis could be interpreted as an analysis of the effects of increase in competition, for a given degree of openness of the economy, when an increase in the actual trade takes place.

That said, it doesn't necessarily mean that globalization had no effect on inflation dynamics. Throughout my analysis I maintain the nominal rigidity component of the slope unchanged. This is not because the frequency of price changes is unaffected by a more global environment. It is simply because it is reasonable to assume that it is not the amount of trade per se that should induce a more frequent adjustment of prices. Price stickiness is instead typically motivated by re-optimization costs, which are essentially driven by the cost of gathering information.

Moreover, the claims that globalization affect the frequency of price adjustment go both ways. On one hand, Rogoff (2003) argues that globalization has led to greater price flexibility - in the model this translates in a lower α, hence in a steepening of the curve. On the other hand, if globalization has brought an overall lower level of inflation, as argued by many, than there is less incentive to revise prices often, because the cost of price misalignment is lower. Endogeneizing the frequency of price adjustment is indeed an active area of research.

8 Appendix

This appendix explains how I compute the elasticity of marginal cost defined in expression (29) as a function of the traded goods N. This involves computing how aggregate output Y varies with N, and calibrating the parameter Φ. From expression (28), one derives the steady state real marginal cost as

$$s = \frac{1}{1-a} w \left(xY + \Phi\right)^{\frac{a}{1-a}}, \tag{39}$$

where w denotes the steady state real wage. Assuming a fairly standard preference specification: $u(C, h) = \log C - \frac{1}{1+\nu} h^{1+\nu}$, the real wage is $w_t = H_t^{\nu} C_t$. Aggregate hours H_t are

$$H_t = \int_0^N h_t(i)\, di = \int_0^N \left(y_t(i) + \Phi\right)^{\frac{1}{1-a}} di,$$

where I used the definition of hours in (27). Steady state aggregate hours are then

$$H = N \left(xY + \Phi\right)^{\frac{1}{1-a}},$$

which, substituted in the expression for the equilibrium real wage, allows to rewrite (39) as

$$s = \frac{1}{1-a} N^{\nu} \left(xY + \Phi\right)^{\frac{\nu + a}{1-a}} Y. \tag{40}$$

From (31) in the text the steady state real marginal cost is $s = 1/N\overline{\mu}x$. Combining this expression with (40) we obtain that

$$xY + \Phi = \left[\frac{1-a}{\overline{\mu} x Y N^{1+\nu}}\right]^{\frac{1-a}{\nu+a}}. \tag{41}$$

This expression defines a concave, increasing function $Y = Y(N)$. For a given calibration of the parameters a, ν and Φ, any value of N determines a value of Y, which, together with the value of x, allows to compute a value for the elasticity $\overline{s}_y$. I set the parameter ν to be equal to 2, which corresponds to assuming a Frisch elasticity of labor supply of .5, the high end of the range typically found in micro studies; $1-a=.68$, to roughly match the average observed labor share for the U.S. To calibrate Φ I first use the entry condition to establish a zero-profit upper bound to the fixed cost of production:

$$\Phi^u = \frac{1}{N^{1-a}}\left(1-\frac{1-a}{\overline{\mu}}\right)$$

Then I set Φ sufficiently close but strictly lower than Φ^u to allow entry of new firms with positive profits: $\Phi = .2$. The results are not very sensitive to the range of values chosen for these parameters, since they have mostly a scale effect on $\overline{s}_y$, and hence on ζ, without affecting its curvature.

References

[1] Bakhshi, H., Khan, H., Burriel-Lombart, P. (forthcoming) The new Keynesian Phillips curve under trend-inflation and strategic complementarity, *Journal of Macroeconomics.*

[2] Ball, L., 2006. Has Globalization Changed Inflation?, NBER wp 12687.

[3] Benassy, J-P., 1996. Taste for variety and optimum production patterns in monopolistic competition, *Economics Letters* 52: 41-47.

[4] Bernanke, B. Globalization and Monetary Policy. Speech at the Fourth Economic Summit, Stanford Institute for Economic Policy Research, Stanford, March 2006.

[5] Bilbiie, F.O., Ghironi, F., Melitz, M.J., 2006a. Endogenous Entry, Product Variety and Business Cycle, unpublished.

[6] Bilbiie, F.O., Ghironi, F., Melitz, M.J., 2006b. Monopoly Power and Endogenous Variety in Dynamic Stochastic General Equilibrium: Distortions and Remedies, unpublished.

[7] Borio, C., Filardo A., 2007. Globalization and Inflation: New cross-country evidence on the global determinants of domestic inflation. BIS, unpublished.

[8] Broda,C., Weinstein, D., 2006. Globalization and the Gains from Variety, *Quarterly Journal of Economics,* 121(2)

[9] Chen, N., Imbs, J., Scott, A., 2006. Competition, Globalization and the Decline of Inflation, CEPR discussion paper n. 4695.

[10] Cogley, T., Sbordone A.M., 2005. A search for a structural Phillips curve. Federal Reserve Bank of New York *Staff Reports* No. 203.

[11] Eichenbaum, M., Fisher, J., 2007. Estimating the frequency of price re-optimization in Calvo-style models. *Journal of Monetary Economics.*

[12] Dotsey, M., King, R., 2005. Implications of state-dependent pricing for dynamic macroeconomic models. *Journal of Monetary Economics* 52 (1): 213-242.

[13] Dotsey, M., King, R., Wolman A., 1999. State-dependent pricing and the general equilibrium dynamics of money and output. *Quarterly Journal of Economics* 114 (3): 655-690.

[14] Gali, J., Monacelli, T., 2005. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. *Review of Economic Studies*, 72: 707-734.

[15] Gust, C, Leduc S., Vigfusson, R.J., 2006. Trade Integration, Competition and the Decline in Exchange-Rate Pass-Through, unpublished.

[16] Ihrig, J., Kamin, S.B., Lindner, D., Marquez, J. Some Simple Tests of the Globalization and Inflation Hypothesis. Board of Governors *International Finance Discussion Paper* n. 893, forthcoming.

[17] International Monetary Fund. 2006. "How Has Globalization Affected Inflation?" World Economic Outlook, Chapter III, April.

[18] Ireland, P. 2005. Changes in the Federal Reserve's Inflation Target: Causes and Consequences, unpublished.

[19] Levin, A., Lopez-Salido, D., Yun, T., 2006. Strategic Complementarities and Optimal Monetary Policy, unpublished.

[20] Kimball, M. S., 1995. The Quantitative Analytics of the Basic Neomonetarist Model. *Journal of Money, Credit and Banking*, vol 27 (4): 1241-1277.

[21] Kohn, D.L., 2006. The Effects of Globalization on Inflation and Their Implications for Monetary Policy, Remarks at the Federal Reserve Bank of Boston's 51st Economic Conference, Chatam, Mass., June 16.

[22] Melitz, M., Ottaviano, G., 2005. Market Size, Trade and Productivity, unpublished.

[23] Mishkin, R., 2007. Inflation Dynamics, NBER working paper n. 13147.

[24] Razin,A., Yuen, C. 2002. The "New Keynesian" Phillips Curve: Closed Economy vs. Open Economy. *Economic Letters*, 75: 1-9.

[25] Rogoff, K., 2003. Globalization and Global Disinflation, Jackson Hole Symposium, August 28-30.

[26] Rogoff, K., 2006. Impact of Globalization on Monetary Policy, Jackson Hole Symposium, August 24-26.

[27] Sbordone, A. M., 2002. Prices and unit labor costs: a new test of price stickiness, *Journal of Monetary Economics* 49 (2).

[28] Woodford, M. 2003. *Interest and Prices. Foundations of a Theory of Monetary Policy.* Princeton University Press.

[29] Yellen, J. Monetary Policy in a Global Environment. Speech at the Conference 'The Euro and the Dollar in a Globalized Economy' University of California at Santa Cruz, May 2006.