*Economic Quarterly—Volume 94, Number 3—Summer 2008—Pages 219–233*

# Nominal Frictions, Relative Price Adjustment, and the Limits to Monetary Policy

Alexander L. Wolman

There are two broad classes of sticky-price models that have become popular in recent years. In the first class, prices adjust infrequently by assumption (so-called time-dependent models) and in the second class prices adjust infrequently because there is assumed to be a fixed cost of price adjustment (so-called state-dependent models). In both types of models it is common to assume that there are many goods, each produced with identical technologies. Consumers have a preference for variety, but their preferences treat all goods symmetrically. These assumptions mean that it is efficient for all goods to be produced in the same quantities. For that to happen, all goods must sell for the same price at any point in time. Assuming that price adjustment is staggered (as opposed to synchronized), the prices of all goods must be constant over time in order for all goods to be produced in the same quantities. If the aggregate price level were changing over time—even at a constant rate—then with staggered price adjustment prices would necessarily differ across goods.

If there are multiple sectors that possess changing relative technologies or that face changing relative demand conditions (because consumers' preferences are changing across goods), then in general it will no longer be efficient to produce all the goods in the same quantities. Equating marginal rates of transformation to marginal rates of substitution may require relative prices to change over time. These efficient changes in *relative* prices across sectors require *nominal* prices to change within sectors. With frictions in nominal

The views here are the author's and should not be attributed to the Federal Reserve Bank of Richmond, the Federal Reserve System, or the Board of Governors of the Federal Reserve System. For helpful comments, the author would like to thank Juan Carlos Hatchondo, Andreas Hornstein, Yash Mehra, and Anne Stilwell. E-mail: alexander.wolman@rich.frb.org.

price adjustment, nominal price changes bring with them costly misallocations within (and perhaps across) sectors.[1]

In the circumstances just described, where efficiency across sectors requires nominal price changes within a sector or sectors, a zero inflation rate for the consumption price index may no longer be the optimal prescription for monetary policy in the presence of sticky prices. Which inflation rate results in the smallest distortions from price stickiness depends on the details of the environment: chiefly, the rates of relative price change across sectors and the degree of price stickiness in each sector. To cite an extreme example, suppose there are two sectors with different average rates of productivity growth. Suppose further that the sector with low productivity growth (increasing relative price) has sticky prices, whereas the sector with high productivity growth has flexible prices. Then it would be optimal to have deflation overall. Deflation would allow the desired relative price increase to occur with zero nominal price changes for the sticky-price goods and, thus, with no misallocation from the nominal frictions.

The principles for optimal monetary policy I have discussed thus far involve only frictions associated with nominal price adjustment. In reality, monetary policy must balance other frictions as well. As the literature on the Friedman rule emphasizes, the fact that money is nearly costless to produce means that it is socially optimal for individuals to face nearly zero private costs of holding money. This requires a near-zero nominal interest rate, which corresponds to moderate deflation. Other frictions are less well understood, but may be just as important. Many central banks have mandates to achieve price stability, and the fact that my models do not necessarily support this objective does not mean it is misguided; that is, my models may still be lacking. The message of this paper is not that monetary policy should deviate from zero inflation in order to minimize distortions associated with nominal price adjustment. Rather, it is that in the presence of fundamental relative price changes and nominal price adjustment frictions, there is no monetary policy—zero inflation or otherwise—that can render those frictions costless.

Section 1 works through the optimality of price stability in a benchmark one-sector model. Section 2 describes a two-sector model where a trend in relative productivities means that all prices cannot be stabilized. In Section 2 I also display U.S. data for broad categories of consumption, which display trends in relative prices. The data show that even *on average*, it is not possible to stabilize all nominal prices; trends in relative prices mean that if the price of one category of consumption goods is stabilized then prices for the other categories must have a trend. Furthermore, relative price trends in the United

[1] These statements are qualitative ones. Unless monetary policy is extremely volatile or generates very large inflation or deflation, most current models attribute relatively small welfare costs to nominal frictions.

States have been rather large; since 1947, the price of the services component of personal consumption expenditures has risen by a factor of five relative to the price of the durable goods component. Sections 3 and 4 provide a brief review of existing literature on relative price variation and monetary policy. In contrast to the material in Section 2, the existing literature has concentrated on random fluctuations in relative prices around a steady state where relative prices are constant. Section 3 reviews the literature on cyclical variation in relative prices, and Section 4 summarizes related work on wages (a form of relative price) and prices across locations. Section 5 concludes.

## 1. OPTIMALITY OF PRICE STABILITY IN A ONE-SECTOR MODEL

Here I formalize the explanation for how price stability eliminates the distortions associated with price stickiness in a one-sector model. Suppose there are a large number of goods, specifically a continuum of goods indexed by $z \in [0, 1]$, and suppose that consumers' utility from consuming $c_t(z)$ of each good is given by $c_t$, where that utility is determined by the following aggregator function:

$$c_t = \left[\int_0^1 c_t(z)^{(\varepsilon-1)/\varepsilon} dz\right]^{\varepsilon/(\varepsilon-1)}, \tag{1}$$

where $\varepsilon$ is the elasticity of substitution in consumption between different goods. Suppose that each good is produced with a technology that uses only labor input, and that one unit of the consumption good can be produced with $1/a_t$ units of labor input:

$$c_t(z) = a_t n_t(z), \quad \text{for } z \in [0, 1]. \tag{2}$$

Thus, $a_t$ is a productivity factor common to all goods. I assume that $a_t$ is exogenous. In particular, monetary policy has no effect on $a_t$. Finally, there is a constraint on the total quantity of labor input:[2]

$$\int_0^1 n_t(z) \leq N_t. \tag{3}$$

Without specifying anything about the structure of markets or price-setting behavior, I can discuss efficient production of consumption goods in this model. Efficiency dictates that the marginal rate of substitution in consumption be equated to the marginal rate of transformation in production. That is, the rate at which consumers trade off goods according to their preferences

[2] In models with inelastic labor supply, $N_t$ would be a constant equal to the time endowment. Otherwise, $N_t$ would be equal to the difference between the time endowment and the endogenous quantity of leisure.

(represented by [1]) should be equal to the rate at which the technology (represented by [2]) allows goods to be traded off against one another in production.

For the aggregator function in (1), consumers' marginal rate of substitution between any two goods, $c_t(z_0)$ and $c_t(z_1)$, is given by

$$mrs\left(c_t(z_0), c_t(z_1)\right) = \frac{\partial c_t / \partial c_t(z_0)}{\partial c_t / \partial c_t(z_1)} = \left(\frac{c_t(z_0)}{c_t(z_1)}\right)^{-1/\varepsilon}. \quad (4)$$

For the simple linear technology in (2), the marginal rate of transformation between any two goods indexed by $z_0$ and $z_1$ is unity: Reducing the labor used in the production of $z_0$ by one unit yields a $1/a_t$ unit reduction in $c_t(z_0)$, and transferring that labor to the production of $z_1$ yields an identical $1/a_t$ unit increase in $c_t(z_1)$. Given my assumptions about consumers' preferences and the technology for producing goods, equating the marginal rate of substitution to the marginal rate of transformation requires that each good, $z$, be produced in the same quantity. Only then can it be the case that

$$\left(c_t(z_0)/c_t(z_1)\right)^{-1/\varepsilon} = 1 \quad (5)$$

for all $z_0, z_1 \in [0, 1]$.

At this point I know that efficiency requires all goods be produced in the same quantity. Under what conditions are the allocations in sticky-price models efficient? A standard assumption in sticky-price models, and an assumption I will make here, is that each individual good is produced by a separate monopolist. Because the Dixit-Stiglitz aggregator function (1) means that each good has many close substitutes, monopoly production of each good leads to an overall market structure known as monopolistic competition.

The demand curve faced by the monopoly producer of any good, $z$, is

$$c_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon} c_t, \quad (6)$$

where $P_t$ is the price index for the consumption basket and is given by

$$P_t = \left[\int_0^1 P_t(z)^{1-\varepsilon} dz\right]^{1/(1-\varepsilon)}. \quad (7)$$

The demand curve and the price index can be derived from the consumer's problem of choosing consumption of individual goods in order to minimize the cost of one unit of the consumption basket (see, for example, Wolman 1999).

From the demand functions and the efficiency condition, it is clear that efficiency requires all goods to have the same price. If price adjustment is infrequent (i.e., if prices are sticky) and if price adjustment is staggered across firms, then all goods can have the same price only if the aggregate price level is constant. If the price level varied over time, then changes in the price level would occur with only some firms adjusting their price, which would be inconsistent with all firms charging the same price. In somewhat simplified form, this is the reasoning behind optimality of price stability in sticky-price models (see, for example, Goodfriend and King 1997, Rotemberg and Woodford 1997, and King and Wolman 1999).

## 2. TREND VARIATION IN RELATIVE PRICES

The model sketched in the previous section is a useful benchmark, but it is obviously unrealistic to suppose that the consumption goods valued by households are all "identical" in the sense of entering preferences symmetrically (1) and being produced with identical technologies (2). Departing from that benchmark, research on monetary policy in multisector sticky-price models has concentrated on the extent to which cyclical fluctuations in the determinants of relative prices interfere with the ability of monetary policy to eliminate sticky-price distortions on a period-by-period basis, and the related question of whether overall price stability remains optimal in such environments. However, more fundamental is the question of whether a trend in relative prices affects the ability of monetary policy to eliminate distortions even in steady state, and the related question of whether price stability is optimal *on average*, i.e., whether the optimal rate of inflation is zero. I consider these questions in Wolman (2008) and I draw on that analysis in what follows, emphasizing the former question (Can distortions be eliminated in a steady state?).

### Theory

In contrast to the one-sector framework, suppose that consumers have Cobb-Douglas preferences over *two* composite goods, and that each of those composites has the characteristics of the single consumption aggregate ($c_t$) in the previous section. Here, $c_t$ will denote the overall consumption basket comprised of the two types of goods, and $c_{1,t}$ and $c_{2,t}$ will denote the sectoral baskets each comprised of a continuum of individual goods. The overall basket is now

$$c_t = c_{1,t}^{\nu} c_{2,t}^{1-\nu}, \tag{8}$$

and the sectoral baskets are

$$c_{k,t} = \left( \left[ \int_0^1 c_{k,t}(z)^{(\varepsilon-1)/\varepsilon} dz \right]^{\varepsilon/(\varepsilon-1)} \right), \quad \text{for } k = 1, 2. \tag{9}$$

As before, $\varepsilon$ is the elasticity of substitution between individual goods within a sector. The elasticity of substitution across sectors is unity, and the sectoral expenditure shares for the two sectors are $\nu$ and $1 - \nu$. The constraint on labor input is

$$\int_0^1 n_{1,t}(z) + \int_0^1 n_{2,t}(z) \leq N_t. \tag{10}$$

Technology for producing individual goods is the same as above,

$$c_{k,t}(z) = a_{k,t} n_{k,t}(z), \quad \text{for } k = 1, 2, \tag{11}$$

except that now I allow for different levels of productivity ($a_{k,t}$) in the two sectors. Again, productivity is exogenous, or unaffected by monetary policy.

***Quantities and efficiency***

I can analyze efficiency just as I did in the one-sector model. However, here there are two dimensions of efficiency to be concerned with: efficiency within sectors and efficiency across sectors. Within either sector, the analysis is identical to that in the one-sector model. Efficiency within a sector requires equal production of each good,

$$\left(c_{k,t}(z_0)/c_{k,t}(z_1)\right)^{-1/\varepsilon} = 1 \text{ for } z_0, z_1 \in [0,1], \text{ for } k = 1, 2, \tag{12}$$

because of symmetry in preferences and identical technologies. Across sectors, the marginal rate of substitution is

$$\begin{aligned} mrs\left(c_{1,t}(z_0), c_{2,t}(z_1)\right) &= \left(\frac{\nu}{1-\nu}\right)\left(\frac{c_{2,t}}{c_{1,t}}\right)\left(\frac{c_{1,t}(z_0)/c_{1,t}}{c_{2,t}(z_1)/c_{2,t}}\right)^{\frac{-1}{\varepsilon}}, \\ \text{for } z_0, z_1 &\in [0,1], \end{aligned} \tag{13}$$

and the marginal rate of transformation is

$$mrt\left(c_{1,t}(z_0), c_{2,t}(z_1)\right) = \left(\frac{a_{2,t}}{a_{1,t}}\right), \text{ for } z_0, z_1 \in [0,1]. \tag{14}$$

Note that in order for efficiency to hold across sectors, it must hold within sectors; if within-sector efficiency does not hold, then from (12) the marginal rate of substitution varies across combinations of $z_0, z_1$. With the marginal rate of transformation independent of $z$ (from [14]), it is not possible for the marginal rate of substitution to be equated to the marginal rate of transformation for all combinations of $z_0, z_1$ unless there is efficiency within each sector. Efficiency within and across sectors then holds if and only if

$$c_{k,t}(z_0) = c_{k,t}(z_1) \text{ for } z_0, z_1 \in [0,1], \text{ for } k = 1, 2, \tag{15}$$

and

$$\frac{a_{1,t}}{a_{2,t}} = \left(\frac{1-\nu}{\nu}\right)\left(\frac{c_{1,t}}{c_{2,t}}\right). \tag{16}$$

The former condition states that quantities must be identical for all goods within a sector. The latter condition states that the ratio of sectoral consumptions should be proportional to the ratio of sectoral productivities; thus, if the ratio of sectoral productivities changes over time, then the ratio of sectoral consumptions must change in order to maintain efficiency.

***Prices and efficiency***

As in the one-sector model, in order to determine the conditions under which efficiency holds I need to specify market structure and pricing behavior. I make analogous assumptions to the one-sector model, namely that individual goods are produced by monopolists, which implies monopolistic competition among producers.

The demand curve faced by the monopoly producer of a good $z$ in sector $k$ is

$$c_{k,t}(z) = \left(\frac{P_{k,t}(z)}{P_{k,t}}\right)^{-\varepsilon} c_{k,t}, \; k = 1, 2, \tag{17}$$

where $P_{k,t}$ is the price index for the sector $k$ consumption basket,

$$P_{k,t} = \left[\int_0^1 P_{k,t}(z)^{1-\varepsilon} dz\right]^{1/(1-\varepsilon)}. \tag{18}$$

The index of sector $k$ consumption in (17) can be replaced by the appropriate demand function,

$$c_{1,t} = \nu \left(\frac{P_{1,t}}{P_t}\right)^{-1} c_t, \text{ or} \tag{19}$$

$$c_{2,t} = (1-\nu)\left(\frac{P_{2,t}}{P_t}\right)^{-1} c_t. \tag{20}$$

These demand functions, as well as the overall price index in the two-sector model ($P_t$), are derived from the consumer's problem of choosing sectoral consumption in order to minimize the cost of one unit of the consumption basket. The price index is given by

$$P_t = \left(\frac{P_{1,t}}{\nu}\right)^{\nu} \left(\frac{P_{2,t}}{1-\nu}\right)^{1-\nu}. \tag{21}$$

Note from (19) and (20) that the share of consumption spending (expenditure share) going to sector one (sector two) is constant and equal to $\nu$ (equal to $1-\nu$).

From the demand curves for individual goods (17) and the within-sector efficiency condition (15), it is again clear that efficiency requires all goods within a sector to have the same price:

$$P_{k,t}(z_0) = P_{k,t}(z_1) \text{ for } z_0, z_1 \in [0, 1], \text{ for } k = 1, 2. \tag{22}$$

Across sectors, because efficiency requires relative consumptions to move with relative productivities, sectoral relative prices must vary with relative productivities. Combining (16) with (19) and (20) yields

$$\frac{a_{1,t}}{a_{2,t}} = \frac{P_{2,t}}{P_{1,t}}. \tag{23}$$

Working now in terms of prices instead of quantities, conditions (22) and (23) are necessary and sufficient for efficiency.

Earlier I stated that productivity in each sector was exogenous. Now I will make the further assumption that there is a trend in the growth rate of sector one's productivity relative to sector two's productivity:

$$\frac{a_{1,t}}{a_{2,t}} = (1+\gamma)^t \ , \ \ t = 0, 1, 2, ..., \gamma > 1, \tag{24}$$

where $\gamma$ is an exogenous parameter representing relative productivity growth in sector one. Substituting this relationship into the second efficiency condition (23) implies

$$\frac{P_{2,t}}{P_{1,t}} = (1+\gamma)^t \ ; \tag{25}$$

efficiency requires the price of sector two's composite good to rise over time relative to the price of sector one's composite good. The requirement that there be a trend in the relative price $P_{2,t}/P_{1,t}$ could be satisfied with a variety of different combinations of nominal price behavior for $P_{2,t}$ and $P_{1,t}$, but each of those combinations involves at least one nominal price having a nonzero rate of change. In other words, when there is a trend in relative productivity growth across the two sectors, some nominal prices must change in order for efficiency to hold. But now there is a contradiction, because from the requirement that prices be identical for all goods within a sector (22), I can use the same reasoning as in the one-sector model of Section 1 to conclude that efficiency with price stickiness requires zero price changes within each sector. It is not possible to have both zero price changes within each sector and a nonzero rate of price change in at least one sector.

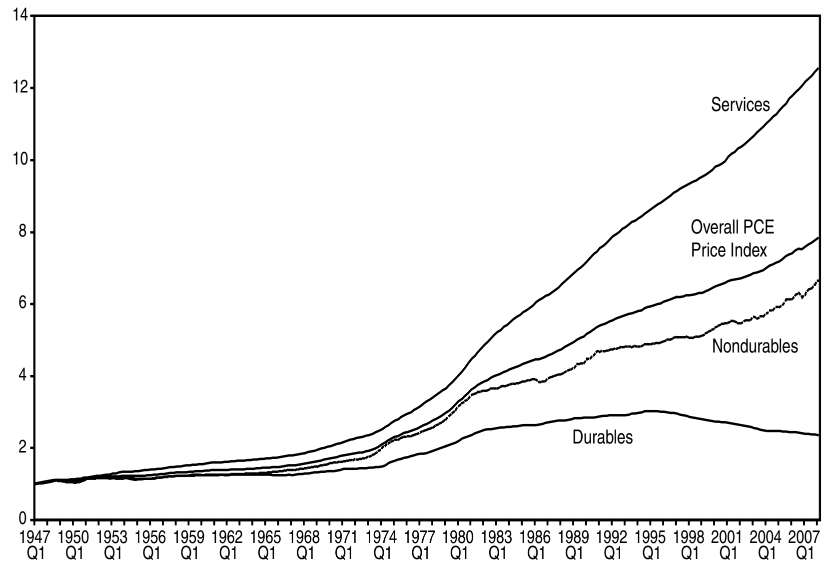
Wolman (2008) shows how one can determine the optimal rate of inflation in a sticky-price model that has the features described here. For my purpose, it is enough to conclude that when there are different trend productivity growth rates across sectors, price stickiness inevitably leads to some real distortions that cannot be undone by monetary policy.

## Measurement: Price Stickiness and Relative Price Trends

It is one thing to make a theoretical argument showing that, given certain assumptions, monetary policy cannot overcome the frictions associated with price stickiness. Here I take the next step and argue that those conditions seem to exist in the United States. The conditions I discuss are, first, that there is some price stickiness (infrequent price adjustment), and second, that there are trends in the relative prices of different categories of consumption goods.

Concerning infrequent price adjustment, a vast literature has arisen in recent years reporting on the behavior of the prices of large numbers of individual

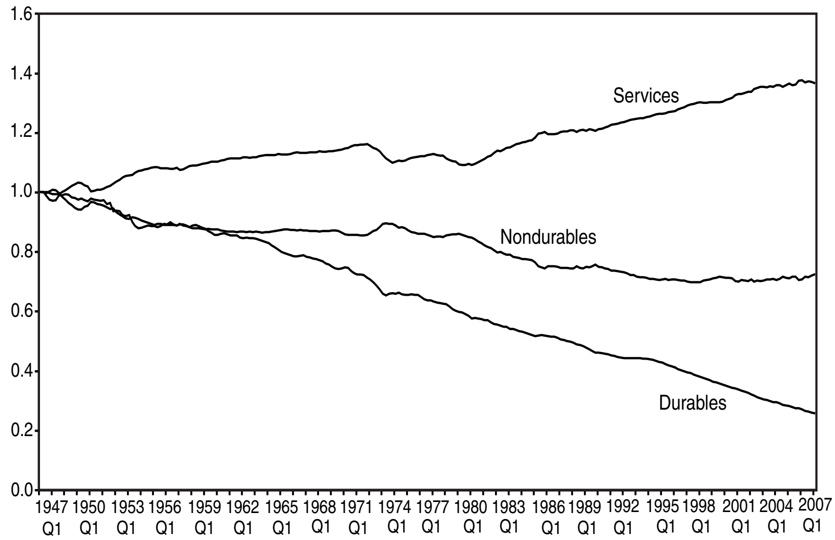
**Figure 1 Sectoral Prices Indexes**




goods. The seminal paper in this literature is by Bils and Klenow (2004), who study individual prices that serve as inputs into the United States Bureau of Labor Statistics (BLS) Consumer Price Index computations. Although their headline result is about price adjustment being more frequent than previous studies had estimated, they show that there is substantial heterogeneity in the frequency of price adjustment. The median price duration in their sample is 4.3 months, but one-third of consumption expenditure is on goods and services with price durations greater than 6.8 months, and one-quarter is on goods and services with price durations greater than 9 months.

In the model in Section 2, there were two sectors, and thus only one independent sectoral relative price. In contrast, the BLS compiles price indexes for hundreds of categories of consumption goods. Thus, there are hundreds of sectoral relative prices one could study. Here I will report on relative prices from highly aggregated categories of consumption: durable goods, nondurable goods, and services. Price indexes for these categories are reported by the United States Commerce Department's Bureau of Economic Analysis. Figure 1 plots the price indexes for durables, nondurables, and services from 1947 to 2008. There are clear positive trends in the prices of services and nondurables relative to durables. Since 1947, the price of nondurables relative to durables

**Figure 2 "Zero-Inflation" Price Indexes**




has risen by a factor of more than two, and the price of services relative to durables has risen by a factor of more than five. With these trends in relative prices, it would not have been possible to stabilize the individual prices of each consumption category. Figure 2 displays the counterfactual paths of the price indexes from Figure 1 that are consistent with zero inflation in each quarter, given the historical values for relative prices and expenditure shares; stabilizing the overall price level would have required the nominal price of durables to fall by almost 80 percent and the nominal price of services to rise by almost 40 percent.[3]

Together, the presence of infrequent individual price adjustment and trends in the relative prices of different consumption categories makes clear that monetary policy cannot eliminate the frictions associated with nominal price

[3] Figure 2 is constructed as follows: First, I normalize the levels of the sectoral price indexes at one in the first quarter of 1947. Then, for each subsequent quarter, I divide the gross rate of sectoral price change for each sector by the expenditure share weighted average of the gross rates of sectoral price changes (that is, I divide by the overall inflation rate). The resulting quotient for each sector is the rate of change of the zero-inflation price indexes in Figure 2. By construction, the expenditure share weighted average of the rates of price change for the zero-inflation sectoral price indexes is zero.

adjustment. In other words, while monetary policy can stabilize an overall price index, it cannot stabilize all individual prices. To the extent that individual price adjustment is costly, either directly (state-dependent pricing) or indirectly (time-dependent pricing), stability of individual prices is required if nominal frictions are to be eliminated.

## 3. CYCLICAL VARIATION IN RELATIVE PRICES

Thus far I have concentrated on the limits to monetary policy when there is a trend in the relative prices of goods with sticky nominal prices. In this setting monetary policy cannot stabilize all nominal prices, even in the absence of shocks. In contrast, most of the growing literature on relative prices and monetary policy has focused on optimal stabilization. That is, the literature has assumed that the optimal average inflation rate (the inflation target) is zero—price stability—and then gone on to study how monetary policy should make inflation behave in response to various shocks. A number of papers in this literature have used multisector models to study cyclical analogues of the kind of issues discussed in the previous section. I review some of them here.

The most influential early paper in this line of research is by Aoki (2001). In Aoki's paper there are sector-specific productivity shocks that make it infeasible to stabilize all nominal prices. However, one of the two sectors in Aoki's model has flexible prices. Thus, inability to stabilize all prices does not prevent monetary policy from neutralizing nominal frictions. Optimal monetary policy involves stabilizing prices in the sticky-price sector, allowing prices in the other sector to fluctuate with relative productivity.

Subsequently, other authors have extended Aoki's analysis to environments where price stickiness in both (or all) sectors means that monetary policy cannot neutralize the nominal frictions. Huang and Liu (2005) study a model with both intermediate and final goods sectors, with price stickiness in both sectors. As in Aoki's paper, productivity shocks are sector-specific, but they inevitably lead to distortions because of price stickiness in both sectors. Huang and Liu emphasize that stabilizing consumer prices at the expense of highly volatile producer prices can be quite costly; optimal monetary policy should place nonnegligible weight on producer price inflation.

Like Huang and Liu, Erceg and Levin (2006) study a model with two sticky-price sectors. Instead of intermediate and final goods, the sectors produce durable and nondurable final goods.[4] As in Huang and Liu's paper, sector-specific productivity shocks ought to involve relative price changes, and with price stickiness these relative price changes necessarily involve distortions. However, the presence of durable goods gives the model some

[4] Erceg and Levin's paper also includes wage stickiness, which I will discuss in the next section.

additional interesting properties. A shock to government spending—an aggregate shock—now also should involve relative price changes, because it raises the real interest rate, making durable goods less attractive. With sticky prices in both sectors, stabilizing prices in both sectors is infeasible in response to a government spending shock. Thus, even an aggregate shock can inevitably lead to nominal distortions in a multisector model.[5]

## 4. WAGES AND PRICES ACROSS LOCATIONS

By now it should be clear that when individual goods prices are sticky, shocks that optimally change the relative price across sectors inevitably restrict the monetary authority's ability to achieve efficient allocations. Elements of this reasoning also apply to wage stickiness and to prices across regions in a currency union.[6]

The labor market can be thought of as a sector, and if nominal prices in that sector are sticky (i.e., if nominal wages are sticky) then aggregate shocks that require real wage adjustment will lead to inefficiencies, even under optimal monetary policy. Erceg, Henderson, and Levin (2000) work through the details in a model with sticky wages and prices. Wage stickiness is introduced in a similar manner to price stickiness: Firms must assemble a range of different types of labor inputs, and the supplier of each input has monopoly power and sets her wage only occasionally. In this framework, it is not optimal to completely stabilize prices or wages, but in general higher welfare is achieved by stabilizing wage inflation than by stabilizing price inflation. Wage dispersion has two costs in the model: it makes production less efficient, and it is disliked by households, who would prefer to spread their labor input evenly over all firms. Price dispersion has only the analogue to the first cost (that is, it makes consumption of the aggregate good less efficient), and this helps to explain why wage inflation takes priority over price inflation. Another factor that works toward stabilizing wage inflation is that the productive inefficiency from wage dispersion affects each intermediate good and feeds through into inefficient production of final goods. In contrast, price dispersion leads only to inefficient production of final goods.[7]

Amano et al. (2007) use a model similar to that of Erceg, Henderson, and Levin to address trend instead of cyclical issues. They assume there is trend productivity growth so that the real wage should rise over time. In a steady state (balanced growth path), a rising real wage means that the nominal wage

[5] There are many other recent papers that study multisector models with nominal rigidities. They include Mankiw and Reis (2003, to be discussed in the next section), Carlstrom et al. (2006), Carvalho (2006), and Nakamura and Steinsson (2008).

[6] Erceg, Henderson, and Levin (2000) recognized the generality of this point.

[7] Similar reasoning may help to explain Huang and Liu's (2005) quantitative findings regarding producer price inflation, mentioned previously.

must be rising or nominal prices must be falling. With infrequent adjustment for both wages and prices, any such scenario involves distortions. Amano et al. show that optimal monetary policy involves slight deflation so that nominal wages are rising at a rate lower than real wages—a compromise between constant wages and constant prices.

Mankiw and Reis (2003) provide a general framework for thinking about optimal monetary policy in the presence of wage and price stickiness as well as sectoral considerations. They frame the monetary policy problem as choosing the appropriate index of prices and wages to stabilize. Consistent with Erceg, Henderson, and Levin (2000), Mankiw and Reis find that nominal wages carry large weight in the "price index" that should be stabilized.

Benigno (2004) studies optimal monetary policy in a two-region currency area. If nominal prices are sticky in both regions and real factors lead to efficient relative price variation across regions, then once again monetary policy cannot eliminate the real effects of price stickiness. The optimal monetary policy problem involves trading off price distortions in the two regions.

## 5. CONCLUSION

If prices or wages are sticky in only one sector of an economy, and if there is no heterogeneity across regions, then monetary policy can undo the effects of price stickiness. However, if there is more than one sector with sticky prices, or if wages and prices are sticky, or if there are heterogeneous regions, then nominal rigidities cause distortions under *any* monetary policy.[8] I described several examples of these distortions, emphasizing an underappreciated one, trending relative prices across sectors.

Macroeconomists are acutely aware of the limited ability of monetary policy to counteract real distortions that may be present in the economy (for example, search frictions in labor markets or monopoly power in goods markets). However, we have been perhaps less modest about the ability of monetary policy to counteract nominal distortions—in particular price adjustment frictions. A recent literature on monetary policy in multisector models with price stickiness has served to make us more modest, and this paper aims to draw attention to that literature.

[8] Loyo (2002) points out that if different sectors have different currencies, then nominal rigidities can be undone. That possibility is intriguing but not currently relevant.

## REFERENCES

Amano, Robert, Kevin Moran, Stephen Murchison, and Andrew Rennison. 2007. "Trend Inflation, Wage and Price Rigidities, and Welfare." Bank of Canada Working Paper 07-42.

Aoki, Kosuke. 2001. "Optimal Monetary Policy Response to Relative Price Changes." *Journal of Monetary Economics* 48: 55–80.

Benigno, Pierpaolo. 2004. "Optimal Monetary Policy in a Currency Area." *Journal of International Economics* 63 (July): 293–320.

Bils, Mark, and Peter Klenow. 2004. "Some Evidence on the Importance of Sticky Prices." *Journal of Political Economy* 112 (October): 947–85.

Carlstrom, Charles T., Timothy S. Fuerst, Fabio Ghironi, and Kólver Hernández. 2006. "Relative Price Dynamics and the Aggregate Economy." Manuscript, http://www2.bc.edu/˜ghironi/CaFuGhiroHeRelPrices082206.pdf (August).

Carvalho, Carlos. 2006. "Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks." *Frontiers of Macroeconomics,* Vol. 2, Article 1.

Erceg, Christopher, and Andrew Levin. 2006. "Optimal Monetary Policy with Durable Consumption Goods." *Journal of Monetary Economics* 53: 1341–59.

Erceg, Christopher, Dale Henderson, and Andrew Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (October): 281–313.

Goodfriend, Marvin, and Robert King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy." In *NBER Macroeconomics Annual*, edited by Ben S. Bernanke and Julio Rotemberg. Cambridge, Mass.: MIT Press, 231–82.

Huang, Kevin, and Zheng Liu. 2005. "Inflation Targeting: What Inflation Rate to Target?" *Journal of Monetary Economics* 52 (November): 1435–62.

King, Robert G., and Alexander L. Wolman. 1999. "What Should the Monetary Authority do When Prices are Sticky?" In *Monetary Policy Rules,* edited by John B. Taylor. Chicago: University of Chicago Press, 349–98.

Loyo, Eduardo. 2002. "Imaginary Money Against Sticky Relative Prices." *European Economic Review* 46 (June): 1073–92.

Mankiw, N. Gregory, and Ricardo Reis. 2003. "What Measure of Inflation Should a Central Bank Target?" *Journal of the European Economic Association* 1 (September): 1058–86.

Nakamura, Emi, and Jón Steinsson. 2008. "Monetary Non-Neutrality in a Multi-Sector Menu Cost Model." Columbia University Working Paper.

Rotemberg, Julio, and Michael Woodford. 1997. "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy." In *NBER Macroeconomics Annual*, edited by Ben S. Bernanke and Julio Rotemberg. Cambridge, Mass.: MIT Press, 297–345.

Wolman, Alexander L. 1999. "Sticky Prices, Marginal Cost, and the Behavior of Inflation." Federal Reserve Bank of Richmond *Economic Quarterly* 85 (Fall): 29–48.

Wolman, Alexander L. 2008. "The Optimal Rate of Inflation with Trending Relative Prices." Manuscript, Federal Reserve Bank of Richmond.