

## real rigidities

Real rigidities are forces that reduce the responsiveness of firms' profit-maximizing prices to variations in aggregate output resulting from variations in aggregate demand. Real rigidities make firms less inclined to take actions that dampen movements in aggregate output, and so increase the responsiveness of output to disturbances. They appear essential to any successful explanation of short-run macroeconomic fluctuations. As a result, various forms of real rigidity pervade modern models of business cycles.

'Real rigidities' is the name given to a large class of business cycle propagation mechanisms. Real rigidities appear essential to any successful explanation of business cycles.

### The definition of real rigidities

Although the term 'real rigidities' appears vague, it in fact refers to a precise concept. Consider an economy of symmetric price-setting firms that is at its flexible-price equilibrium, and suppose that the money supply increases with prices unchanged, so that aggregate output increases. Now ask by how much a representative firm would want to increase its price if it faced no barriers to nominal price adjustment. By definition, the smaller the amount the firm would want to increase its price in response to a given increase in aggregate output, the greater the degree of real rigidity.

One can see the meaning of 'real rigidity' more formally by observing that, in the experiment described above, the profits of the firm that is considering changing its price, neglecting any costs of price adjustment, typically can be written in the form  $V(p_i - p, y)$ , where  $p_i$  is the firm's price,  $p$  is the aggregate price level, and  $y$  is the departure of output from its flexible-price level (all in logs). In most models of this type,  $V(\cdot)$  is a smooth function. The first-order condition for the profit-maximizing price is  $V(p_i^* - p, y) = 0$  (subscripts denote partial derivatives). At the flexible-price equilibrium,  $p_i^* = p$  and  $y = 0$ . Starting from that equilibrium, the derivative of the representative firm's desired relative price,  $p_i^* - p$ , with respect to  $y$  is thus

$$\left. \frac{d(p_i^* - p)}{dy} \right|_{p_i^* = p, y=0} = \frac{V_{12}(0, 0)}{-V_{11}(0, 0)} \equiv \phi.$$

For the flexible-price equilibrium to be stable,  $\phi$  must be positive. By definition, a lower value of  $\phi$  corresponds to greater real rigidity. Note that real rigidity is defined entirely in terms of relations among real variables: it refers to the (lack of) responsiveness of desired real prices to aggregate real output.

The definition of real rigidity in models without symmetric price-setting firms is analogous: any force that reduces the amount that price setters would change their relative prices in response to movements in aggregate output that are the result of changes in aggregate demand is a real rigidity.

### Real rigidities and business cycles

Real rigidities are crucial to business cycles. At a general level, real rigidities make firms less inclined to take actions that dampen movements in aggregate

output. As a result, they increase the responsiveness of output to disturbances.

The importance of real rigidities is easiest to see in a static model where firms face fixed costs of changing prices. Consider the model sketched above, with two extensions. First, replace the profit function with a second-order approximation around the flexible-price equilibrium. This implies that the representative firm's loss in profits from failing to charge its profit-maximizing price (neglecting costs of price adjustment) is  $K(p_i - p_i^*)^2$ , where  $K \equiv -V_{11}$ . It also implies that the representative firm's profit-maximizing price is given by  $p_i^* - p = \phi y$ , where  $\phi$  is as defined before. Second, assume that each firm faces a fixed cost  $Z > 0$  of changing its nominal price.

The economy begins at its flexible-price equilibrium. We want to know by how much output can change in response to a change in aggregate demand before firms change their prices. Non-adjustment is an equilibrium as long as the representative firm's losses from failing to adjust are less than  $Z$ . Prior to the shock, the representative firm's price equals the aggregate price level,  $p$ . If the firm adjusts its price, it sets it to the new profit-maximizing level,  $p + \phi y$ . Thus the condition for nonadjustment to be an equilibrium is  $K[p - (p + \phi y)]^2 < Z$ , or  $|y| < 1/(\phi \sqrt{Z/K})$ . Thus, when  $\phi$  is lower – that is, when real rigidity is greater – the range over which aggregate demand shocks affect real activity is greater.

Real rigidities are not just important to models with nominal rigidity, however. Consider, for example, the following minimalist real business cycle model. The markets for labour and goods are perfectly competitive, and the representative firm's production function is  $y_i = a + n_i$  ( $y$  is output,  $a$  is productivity, and  $n$  is labour input, again all in logs). Labour supply is  $n = \gamma w$ ,  $\gamma > 0$ , where  $w$  is the (log) real wage. In this model, the elasticity of profit-maximizing relative prices to demand-driven output fluctuations (that is, to variations in  $y$  with  $a$  fixed, which must come from variations in  $n$ ) equals the elasticity of the real wage with respect to  $y$ , which is  $1/\gamma$ . Thus a larger value of  $\gamma$  corresponds to greater real rigidity.

The production function implies that labour demand is perfectly elastic at  $w = a$ . Labour-market equilibrium therefore requires that  $n = \gamma a$ . A larger value of  $\gamma$  therefore implies that productivity shocks have a larger impact on employment, and thus that the output effects of the shocks are magnified to a greater extent. Thus, even in this purely Walrasian model of fluctuations, real rigidity acts as a propagation mechanism.

Real rigidities also act as amplification mechanisms in dynamic models of price adjustment. Consider an economy with barriers to price adjustment where output is above its flexible-price level, and suppose that some firms have an opportunity to change their prices, and that their new prices will be in effect for more than one period. Greater real rigidity increases the persistence of the departure of output from its flexible-price level, for three reasons. First, as in the static model of price adjustment, it reduces the benefits of price adjustment, and so makes firms more inclined not to adjust at all. Second, the fact that only some firms have the opportunity to adjust means that output will continue to be above its flexible-price level. Greater real rigidity then implies that the firms that adjust will respond by less, thus drawing out the period of above-normal output. Third, the fact that other firms will be in the same situation when they adjust their prices means that they will adjust by less, which in turn dampens the adjustments of the firms that adjust immediately.

There is a close link between real rigidity and strategic complementarity in profit-maximizing prices. If we assume the stylized aggregate demand curve  $y = m - p$  (where  $m$  reflects factors that shift aggregate demand), then the

expression for the representative firm's profit-maximizing relative price,  $p_i^* - p = \phi y$ , implies  $p_i^* = \phi m + (1 - \phi)p$ . Thus greater real rigidity corresponds to greater strategic complementarity in desired prices: when  $\phi$  is lower, each firm wants its price to move more closely with other prices.

Real rigidity and strategic complementarity in desired prices are not identical, however. To see this, suppose the aggregate demand equation is instead  $y = \beta(m - p)$ ,  $\beta > 0$ . Then  $p_i^* = \phi\beta m + (1 - \phi\beta)p$ . Thus  $\beta$  affects strategic complementarity but not real rigidity. And it is real rigidity that is key to cyclical fluctuations. Nonetheless, because of the close link between the two concepts, and because many business cycle models assume  $y = m - p$ , the terms real rigidity and strategic complementarity in prices are often used interchangeably.

### Types of real rigidities

Since any force that reduces the responsiveness of profit-maximizing relative prices to demand-driven output fluctuations is a real rigidity, there are many possible real rigidities. Some might not be commonly thought of as 'rigidities'. For example, as the simple real business cycle model shows, more elastic labour supply is a type of real rigidity.

Such neoclassical sources of real rigidity, however, are almost surely not strong enough to generate output fluctuations of the size and nature that we observe. In Walrasian models, the real wage is likely to rise sharply with the quantity of labour. For this not to occur, either the long-run elasticity of labour supply must be high or the intertemporal elasticity of substitution in labour supply must be high and short-run aggregate fluctuations must have a large transitory component. Neither of these conditions appears to hold in practice. In models of nominal disturbances and barriers to nominal price adjustment, the result is large incentives for price changes, and thus little nominal rigidity. In productivity-driven real business cycle models, the result is small movements in labour input, so that the dynamics of aggregate output largely mimic the dynamics of the underlying productivity shocks. Researchers have therefore turned their attention to non-Walrasian sources of real rigidity.

It appears difficult to understand substantial employment fluctuations without non-Walrasian real rigidities in the labour market. At a general level, what is needed is for some force causing workers to be off their labour supply curves, at least in the short run, so that the cyclical behaviour of the real wage is not governed by the elasticity of labour supply. For example, if there is equilibrium unemployment because of efficiency wages, the cyclical behaviour of the real wage depends on how the efficiency wage varies with aggregate output. As a result, the real wage can be (though it need not be) less procyclical than in a Walrasian labour market, with the result that fluctuations in employment and output are greater.

A more subtle real rigidity in the labour market arises if labour is imperfectly mobile in the short run (because of search frictions, for example), so that each firm faces an upward-sloping labour supply curve rather than perfectly elastic supply at the economy-wide wage. Consider, for example, a firm contemplating cutting its price and increasing production in a recession. With imperfectly mobile labour, this requires paying a higher real wage. Thus the amount the firm wants to reduce its price is smaller – that is, real rigidity is greater.

There can also be important real rigidities in other markets. In the goods market, forces making desired markups countercyclical act as real rigidities.

When desired markups are more countercyclical, then, for a given degree of procyclicality of real marginal costs, desired movements in relative prices are smaller. Countercyclical desired markups can stem from a variety of sources. One simple but potentially important possibility is that, when economic activity is greater, firms' incentives to disseminate information and consumers' incentives to acquire it are greater, and so demand is more elastic.

Another feature of goods markets that can act as a real rigidity is input-output links among firms. If the prices charged by intermediate suppliers are sticky, the costs that firms face for intermediate inputs tend to rise by less than the suppliers' costs in a boom, thereby reducing the amount that firms would raise their prices if they were free to do so.

Capital-market imperfections can also create real rigidities. Capital-market imperfections can cause financing costs to be countercyclical, as higher output increases cash flow (and hence firms' ability to use internal finance) and raises asset values (and hence increases collateral and reduces the cost of external finance). With one component of costs countercyclical, desired prices are less procyclical. To give another example, financial difficulties in recessions can increase the importance of short-term profits to firms relative to expanding their customer base, and so can make desired markups countercyclical.

There is an important distinction between two broad categories of real rigidities. One category consists of forces, such as limited short-run labour mobility among firms, that increase real rigidity by affecting what happens when one firm changes its prices and others do not. The other consists of forces, such as factors that reduce the procyclicality of the real wage, that increase real rigidity by affecting what happens when all firms' output moves together. In terms of the definition of real rigidity as  $V_{12}(0,0)/[-V_{11}(0,0)]$ , the first category consists of forces raising  $-V_{11}(0,0)$ , and the second consists of forces reducing  $V_{12}(0,0)$ .

The distinction between these two categories is important for two reasons. First, real rigidities that result from forces that affect what happens when one firm changes its price with other firms' prices fixed are not relevant to the properties of business cycle models with identical firms and fully flexible prices. Second, the two types of real rigidities have different microeconomic implications. Most importantly, factors that increase real rigidity by affecting what happens when one firm changes its price and others do not increase the costs of departures from the profit-maximizing price; as a result, they typically predict smaller movements in firms' relative prices in response to many types of shocks.

## Selected literature

Ball and Romer (1990) establish that in a static setting, imperfect competition and barriers to nominal adjustment alone are unlikely to generate substantial nominal rigidity. They show the general importance of real rigidities to static menu-cost models and stress that forces making desired real wages relatively unresponsiveness to output fluctuations are likely to be essential to generating substantial nominal rigidity (see also Blanchard and Fischer, 1989, ch. 8). Earlier work by Akerlof and Yellen (1985) incorporates substantial real rigidity in a model of price stickiness, although it does not explicitly analyse the importance of real rigidity to the results. Haltiwanger and Waldman (1989) show that strategic complementarity magnifies the impact of non-responders on equilibrium outcomes, a result that is closely

related to the finding that real rigidities magnify the effects of barriers to price adjustment.

Kimball (1995) establishes the central role of real rigidities to the persistence of output fluctuations in models of staggered price adjustment, and stresses the importance of the distinction between forces that affect what happens when all firms' output moves together and forces that affect what happens when one firm changes its price with other firms' prices fixed (see also Blanchard, 1987). Klenow and Willis (2006) show the differing micro-economic implications of the two categories of real rigidities. Romer (2006, ch. 6) provides a general discussion of the importance of real rigidities to static and dynamic models of nominal rigidity, catalogues many specific real rigidities, and provides numerous references.

Real rigidities pervade modern business cycle models. In real business cycle models, for example, such common features as indivisible labour supply, variable capital utilization and labour hoarding, and learning-by-doing (see, for example, Rogerson, 1988; Burnside and Eichenbaum, 1996; and Chang, Gomes and Schorfheide, 2002) magnify the effects of disturbances precisely because they are real rigidities. In models with price stickiness, some important recent analyses where real rigidities play a central role include Mankiw and Reis (2002), Gertler and Leahy (2006), and Carvalho (2006).

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### See also

cyclical markups;  
monetary business cycle models (sticky prices and wages);  
new Keynesian macroeconomics;  
real business cycles;  
sticky wages and staggered wage setting.

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