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A FRAMEWORK FOR STUDYING MONETARY NON-NEUTRALITY

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ABSTRACT

This paper sets forth a simple general structural model of aggregate output, the interest rate, and the price level. The core of the model is the determination of the level of output as a product-market equilibrium, either competitive or oligopolistic, possible indeterminate because of thick-market externalities. Monetary non-neutrality can affect either product demand or product supply. In either case, monetary policy has leverage over output as well as the price level. The paper develops a two-diagram analysis intended to replace the aggregate demand-aggregate supply diagram.

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Construction of general equilibrium models of the volatility of output and employment has been dominated by the real business cycle models in the past few years. The prototypical real business cycle model posits a source of noise—usually vibrations in the production function—and a propagation mechanism—usually high elasticity of labor supply. As Prescott [1986] has shown, such a model is capable of explaining the observed volatility of output. By invoking a sufficiently high elasticity of labor supply, Prescott shows that the observed fluctuations in productivity are big enough to stimulate flucutations in employment and output of realistic magnitude. Other types of noise, such as shifts in preferences, can help explain the volatility of output within fairly simple aggregate models.

Though the recent upsurge of interest in real business cycle models has called attention to the importance of real sources of fluctuations, monetary non-neutrality and the corresponding importance of monetary sources of fluctuations remain a central topic in macroeconomics. Research on monetary non-neutrality has had two branches. One, best represented by Robert Lucas's [1972] celebrated model of limited information, derives non-neutral outcomes by making highly specific assumptions within an economic model based on otherwise standard principles. The outcome can properly be described as a full economic equilibrium; within the specified restrictions, there are no unexploited opportunities for trade. Interestingly, although Lucas's paper is among the major landmarks of recent macroeconomics, there has been relatively little additional work on monetary nonneutrality in the equilibrium mode. Equilibrium analysis has become

increasingly popular, but almost always "without some features of the payment and credit technologies," in Edward Prescott's [1986] phrase.

The second branch starts from the observation that prices appear to be unresponsive to monetary developments in the short run. Whereas models along the lines of Lucas's derive the unresponsiveness as a feature of general equilibrium, work in the second branch portrays rigidity as rational behavior at the level of the firm. A huge literature, starting from the Phelps volume [1970], has sought to rationalize the following model: Sellers of products or labor services enter into call option contracts with buyers. The contracts predetermine a price in money terms. Later, when information about demand becomes available, the buyer chooses the quantity. Plainly, such contracts create monetary non-neutralities during the period when money prices are predetermined. The question addressed by the research is why rational parties would enter into such contracts.

My purpose in this lecture is to set up a simple general framework for thinking about both real and monetary sources of output volatility. The goal is to be sufficiently general to encompass real business cycle models and models with monetary non-neutrality in both the Lucas and option-contract styles. The framework I develop attempts to push the textbook "aggregate demand-aggregate supply" apparatus to the next stage of analytical development. The most important modification is to relax a very strong assumption of the AD-AS model, that product supply is completely inelastic with respect to all relative prices. Because high elasticity of supply is at the heart of the real business cycle view, there is a fundamental disagreement between the AD-AS

model and that view. Of course, the elasticity of supply is an empirical issue and the AD-AS model is vigorously defended by its proponents as making a realistic assumption that the elasticity is low.

The general model developed here is a simple equilibrium model with two markets—one for produced goods and one for the monetary instruments of the government. Product supply, product demand, and money demand all may contain monetary non-neutralities. In the model, a non-neutrality appears simply as the presence of the money price of goods in the supply and demand functions for goods and its presence with an elasticity different from one in the demand function for money. The model does not commit itself to any particular theory of nonneutrality—that property could arise from misperceptions or from precommitments to nominal payments. In the latter case, the real effects of nominal precommitments could result from option contracts as in the standard model of price rigidity or from the distributional effects of efficient nominal contracts.

One of the clearest ways to see the generalization of the AD-AS model achieved here is to consider the impact of an exogenous rise in product demand on the price level. In the AD-AS model, such a rise shifts AD to the right and leaves AS unchanged. The price level rises. In an equilibrium model with monetary neutrality, on the other hand, the price level falls, because output rises and the money stock remains the same. In the general model developed here, the impact of an increase in product demand on the price level is ambiguous. If product supply is inelastic, then the price level rises. But if product supply is somewhat elastic, then an exogenous increase in product demand will raise

equilibrium output and may result in a lower, not a higher price level.

1. *The model*

The model deals with three jointly determined variables: output, y, the price level, p, and a relative price, r, which may be the real interest rate, the real wage, or the relative price of two kinds of output. The government sets the quantity of its monetary liabilities, M, exogenously. The model is set forth first in general terms; a completely specific example with preferences and technology described in detail will follow. The demand and supply functions have the usual form and interpretation for a general equilibrium model—they characterize the choices made by price-taking actors who can buy and sell the quantities they choose, given preferences, technology, and existing contracts. Throughout the discussion, I will make the simplifying assumption that the government pays interest on money at a rate equal to the market nominal interest rate less a constant. This assumption rules out the type of non-neutrality considered by Tobin [1965]. It also makes it possible to give a sharp definition of monetary nonneutrality in terms of the presence of the price level in the supply or demand functions. The service price of money is always equal to the constant chosen by the government, so it need not appear explicitly in the model.

The product demand schedule is

$$y = D(r,p) \tag{1.1}$$

Demand arises from consumption, investment, and government purchases. If demand depends on the money price level, p, there is a non-neutrality in demand. For example, if nominal contracts have the effect of redistributing income from actors who tend to hold physical wealth to those who tend to hold financial wealth when the money price level changes, p will appear in the demand function.

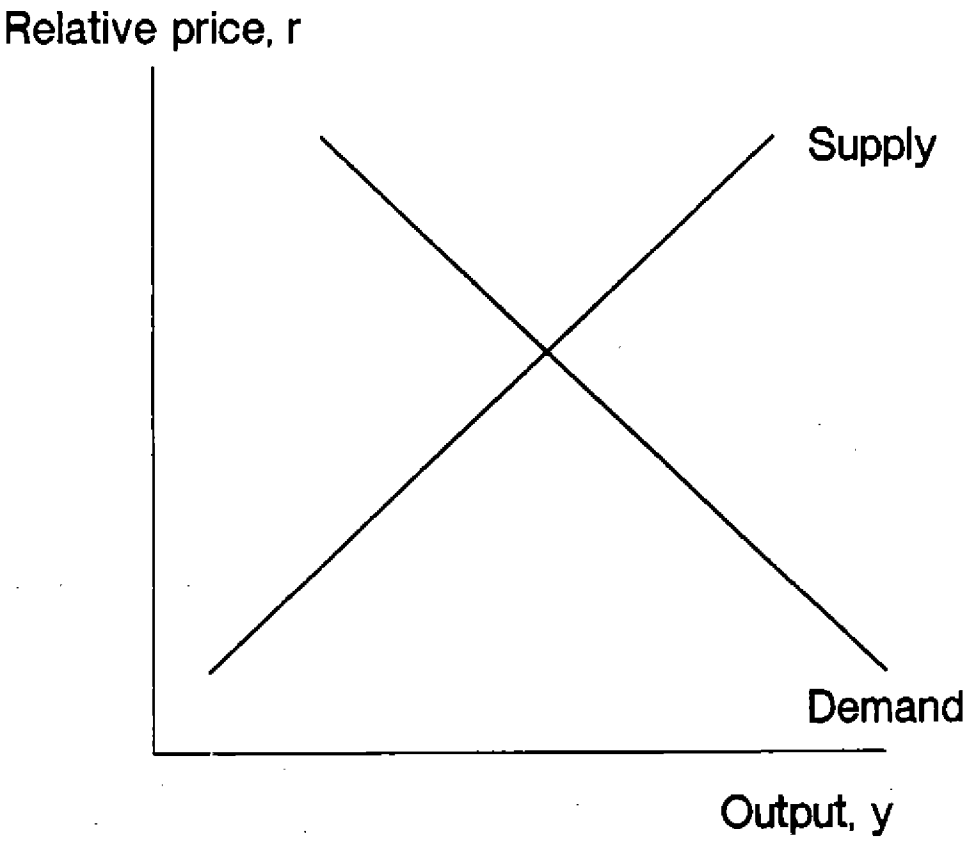
The product supply schedule is

$$y = S(r,p) \tag{1.2}$$

Because the labor market does not appear explicitly, S characterizes choices about the amount of work as well as the technology. Again, p enters if there are non-neutralities. These could arise, for example, from employment contracts that predetermine nominal wages and let firms choose the level of employment subsequently.

Figure 1−1 shows the equilibrium in the goods market. I will adopt the convention of requiring that the economy operate at the intersection of the supply and demand schedules. This is no more than a convention because any considerations of price rigidity or non-market-clearing can be built into the supply and demand schedules. I do not mean to suggest that the point of intersection in Figure 1−1 has any of the favorable properties such as efficiency that occur in an idealized competitive equilibrium. In particular, the equilibrium in Figure 1−1 may well involve under-employed labor because the supply schedule does not reflect the fundamental preferences of workers. Although Figure 1−1's use of

Figure 1-1. The goods market



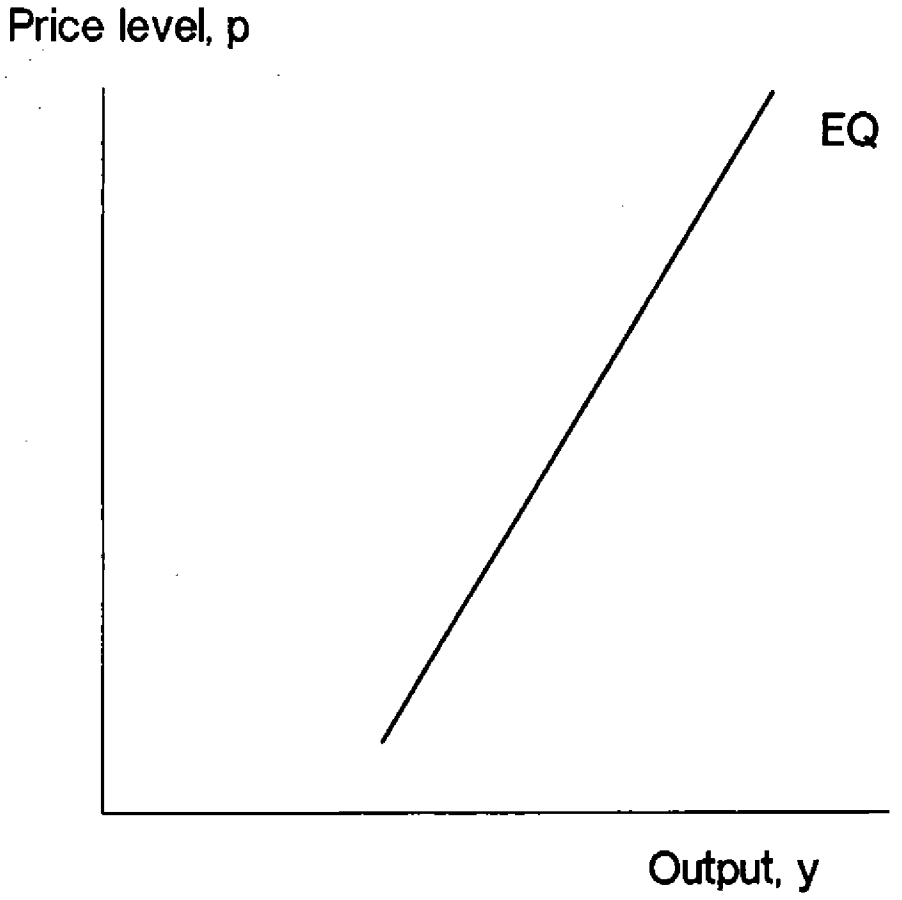
a supply curve suggests competition, the analysis developed here applies in non-competitive cases as well. Absent competition, Figure 1−1 should be replaced by an analysis of the joint determination of the quantity of output and the relative price. If the seller is a monopolist, for example, the analysis would presumably describe the outcome of profit maximization.

The supply and demand schedules in Figure 1−1 are perturbed by the money price level, p. In addition, a vector of real determinants of output, x, shifts supply and demand. The vector x includes shifts of technology, preferences, government purchases and taxes, and noise variables. The equlibrium output in Figure 1−1 can be written as a function of p and x: $y^*(p,x)$. Monetary neutrality holds when equilibrium output is independent of the price level, p. The case of non-neutrality is shown in Figure 1−2. The EQ curve shows that equilibirum output level depends positively on the money price level. The EQ curve will have the same role that the aggregate supply curve does in the standard analysis. However, I will stress that the EQ curve is perturbed by all of the real disturbances, x. For example, the EQ curve will shift to the right if the government raises its purchases of goods. Standard analysis usually teaches that AS is a stable curve that depends only on a narrow range of factors considered by firms in setting prices and determining output.

In models with non-neutrality, considertion of the determinants of the price level is required to complete the model of output volatility. Let the money demand schedule be

$$\frac{M}{p} = F(r,p,x) \tag{1.3}$$

Figure 1-2. The EQ curve



Although it is conventional in macroeconomics to state the demand for money conditional on the choice of the level of consumption or labor supply, the convention of general equilibrium is to put only prices on the right-hand side. In accord with the latter convention, the interest rate or other relative price, r, in $F(r,p,x)$ is not the service price of money (which is a constant determined solely by government policy) but rather the relative price is the determinant of the levels of consumption and labor supply, against which money is held. Again, the presence of p in F is a sign of monetary non-neutrality.

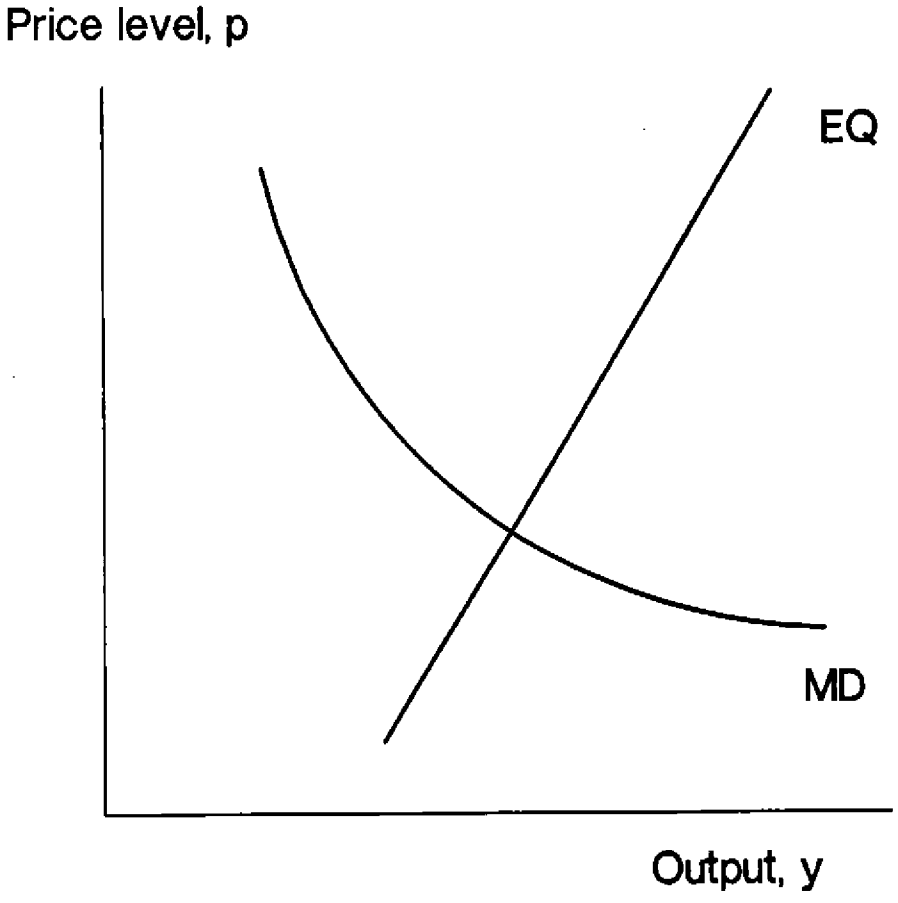
Define the MD curve as the combinations of p and y along which the interest rate or relative price associated with money demand is equal to the interest rate associated with product demand:

Given p, *solve* $\frac{M}{p} = F(r,p,x)$ *for* r *and insert* r *into* $D(r,p)$ *to get* y

Note that the logic of MD is essentially that of finding the intersection of the IS curve (product demand) and the LM curve (money demand). In standard macro analysis, the result is the aggregate demand (AD) schedule. However, I think "aggregate demand" is a misleading term for MD. MD is not the product demand function. Product demand enters the MD schedule only to solve out the relative price variable. It would make just as much sense to use product supply to solve out r. Monetary equilibrium is at the heart of the MD curve.

Figure 1–3 shows the EQ and MD curves in one diagram for the general case of monetary non-neutrality. Under the assumptions

Figure 1-3. Equilibrium



that higher prices stimulate higher supply (S increasing in p) and higher demand (D increasing in p), the EQ curve must slope upward. Absent strong non-neutralities in product demand or money demand, MD slopes downward. On the other hand, if the money price level has a positive effect on product demand, MD is flatter or even upward sloping. This possibility calls attention to a subtle difference between MD and AD. MD is derived from standard demand functions which are defined AS the amount demanded conditional on selling endowments at the given price. AD assumes that the proceeds from sales of endowments is the variable y. At the intersection with EQ or AS, the two assumptions about resources available for consumption are the same, so the difference is one of definition, not substance. However, the definition of the AD curve is confusing to the economist trained in standard general equilibrium.

The comparative statics of Figure 1−3 are reasonably obvious. An increase in the money stock, M, shifts MD to the right and raises p and y. An exogenous increase in product supply raises y and lowers p. An exogenous increase in product demand shifts both EQ and MD to the right, since both schedules involve the product demand function. Output rises but the effect on price is ambiguous. The last property is the only respect in which MD-EQ differs from AD-AS. The reason is the exclusion of product demand from AS, as a result of the very strong assumptions underlying AS.

2. Aggregate supply as a special case of EQ

The *EQ* curve is the centerpiece of the equilibrium real business cycle model, where it describes the level of output resulting from the equalization of product supply and demand by the real interest rate. Product demand has an equal role with product supply. On the other hand, in the *AD-AS* literature, *AS* is strictly a matter of supply. The student in intermediate macroeconomics learns about long-run *AS* as determined by the labor force and the capital stock, and about short-run *AS* as a Phillips curve, but gets no hint that movements in product demand might affect short-run *AS*.

The assumption of *AS* is the exclusion of the real interest rate or other relative price and the real disturbances, x, from the product supply function:

$$y = S(p) \tag{2.1}$$

Under this assumption, $S(p)$ is the *EQ* curve by itself; product demand $D(r,p,x)$ simply determines r. The assumption justifies calling *EQ* the *AS* curve. Empirical evidence on real interest rates and product or labor supply is mixed and inconclusive. The evidence is strong that exogenous increases in product demand such as military buildups cause increases in output. Within the assumptions of the equilibrium real business cycle model, the evidence calls for positive real interest rate effects on product supply. However, non-neutralities in product supply, as set forth in the standard *AD-AS* model, are a competing explanation of the

same facts.

The evidence suggests that temporal agglomeration should be taken seriously in a macroeconomic model. Either intertemporal substitution is very high or thick-market effects are strong enough to overcome workers' dislike of irregular work schedules. The research of West [1986] and Ramey [1988] shows persuasively that producers accept wide fluctuations in the level of output in spite of their ability to offset these fluctuations in part through inventory accumulation and decumulation. Rather than build inventories at times when future increases in output are foreseeable and then draw inventories down when sales become strong, producers generally do the opposite. They accumulate inventories most aggressively when sales are at their peak. The only reasonable conclusion is that producers do not perceive diseconomies of production in occasional bursts. On the contrary, they appear to favor the bunching of production. Their behavior suggests increasing returns, as in the temporal agglomeration model.

If intertemporal substitution in production is high, a substantial interest-elasticity of output is indicated. Producers are indifferent to the timing of output on the cost side; when a high real interest rate rewards early sales in relation to later ones, current production should rise. On the other hand, if the irregularity of output represents the victory of thick-market effects over preferences for smooth work schedules, the interest-elasticty of product supply need not be large. The observed relation of market real interest rates and production confirms this proposition leaves the issue largely unresvolved. The world-wide rise in real interest rates over the past decade did not coincide with any dramatic

acceleration of output. I think the most favorable case for elastic supply is the following. Interpret r not as the market real interest rate, but as the underlying shadow real cost of delaying production. When an increase in product demand raises that shadow cost, producers respond vigorously. The market real rate is such a poor measure of the shadow cost that the supply effect is hard to observe directly. Agency and information problems block the arbitrage of variations in the shadow cost relative to market rates.

3. Monetary policy

Few central banks keep their portfolios on an exogenous path as assumed in the previous discussion. Instead, they react to current economic developments. A simple and broad characterization of policy is that the bank has chooses a line in y-p space describing the combinations of y and p it considers satisfactory for the period. Presumably the line slopes downward; if higher prices are to be tolerated, real activity must be depressed so as to push for lower prices or at least less inflation in the future. Call this line the *MP* curve. If the bank adjusts its portfolio as necessary to keep the economy on the *MP* curve, the *MP* curve takes the place of the *MD* curve in the analysis described earlier. Everything else remains the same.

One example of an *MP* curve is the rectangular hyperbola corresponding to a policy of stabilizing nominal income. In this setting, I pose the same question as at the outset: What happens to the price level and output if there is an exogenous rise in product demand? With the *AS* assumption, the answer is immediate. Product demand has no role in either the *AS* curve or

the *MP* curve, so the price level and output must remain unchanged. With a more general *EQ* curve, the *EQ* curve will shift outward, output must rise, and the price level must fall. In an economy where it was known that central bank policy stabilized nominal income, the positive association between exogenous demand and output would be a strong indication that supply was elastic.

4. Noncompetitive, equilibrium models

The analysis described earlier in the paper assumes competition in the product market, else the concept of a supply function would not be well defined. But recent research in noncompetitive, equilibrium models is easily accommodated. Define the *EQ* schedule as the output resulting from the interaction of the sellers and buyers when the money price level is p. If demand arises from price-takers alone, keep the definition of the *MD* schedule from earlier. If not, it is reasonable to define the *MD* schedule in terms of the real interest rate for the same level of output on the *EQ* curve. If policy can be summarized in an *MP* curve, these questions about *MD* do not arise. Then the comparative statics proceeds as described for the competitive case. A noncompetitive economy does not have an aggregate supply curve, but it has a perfectly well defined *EQ* curve.

5. *Simple fully-developed models*

In this section I will lay out a sequence of simple models in which preferences and technology are completely spelled out.

First, consider an economy with no intertemporal trading opportunities. In each period, labor can be used to produce output at a constant ratio of one to one. Consequently, the real wage is always one. Worker-consumers have Cobb-Douglas preferences over goods consumption, real monetary services, and leisure, with shares α, β and $1-\alpha-\beta$ respectively. The government provides money in quantity M and charges a fixed rental price of μ per period for it. The government uses the proceeds to finance government purchases of x, with any deficit or surplus covered by a lump-sum tax or rebate.

Let z be the real proceeds from the rental of money:

$$z = \mu \frac{M}{\mathrm{p}} \tag{5.1}$$

The public's income after taxes is

$$1 - x + z \tag{5.2}$$

and its real spending on monetary services is

$$z = \beta(1 - x + z) \tag{5.3}$$

Thus

$$z = \frac{\beta}{1-\beta}(1 - x) \tag{5.4}$$

The EQ schedule is just the demand schedule for goods:

$$y = \alpha(1 - x + z) + x \tag{5.5}$$

$$= \frac{\alpha}{1-\beta} + \frac{1-\alpha-\beta}{1-\beta} x$$

This is also the labor and product supply schedule because there is no operational relative price. Note that an increase in product demand—in the form of higher government purchases, x—shifts the EQ schedule to the right. This represents the operation of an income effect in labor supply.

Because there is no interest rate or other relative price determined in the goods market, the MD curve can be derived simply by equating money demand to money supply:

$$\frac{\beta}{1-\beta}(1- x) = \mu\frac{M}{p} \tag{5.6}$$

or

$$p = \frac{1-\beta}{\beta}\frac{\mu}{1-x}M \tag{5.7}$$

The price level is proportional to the money stock and depends positively on government purchases as well. Figure 5−1 shows the vertical *EQ* and horizontal *MD* schedules. The model has monetary neutrality.

To introduce non-neutrality in the most transparent way, I will make labor supply and product demand depend on the money price level. Obviously this does not do full justice to theories based on contractual commitments−it is closer to a theory of money illusion. Let the share α depend on the price level in the following way:

$$\alpha = \alpha_0 \frac{p}{\bar{p}} p \tag{5.8}$$

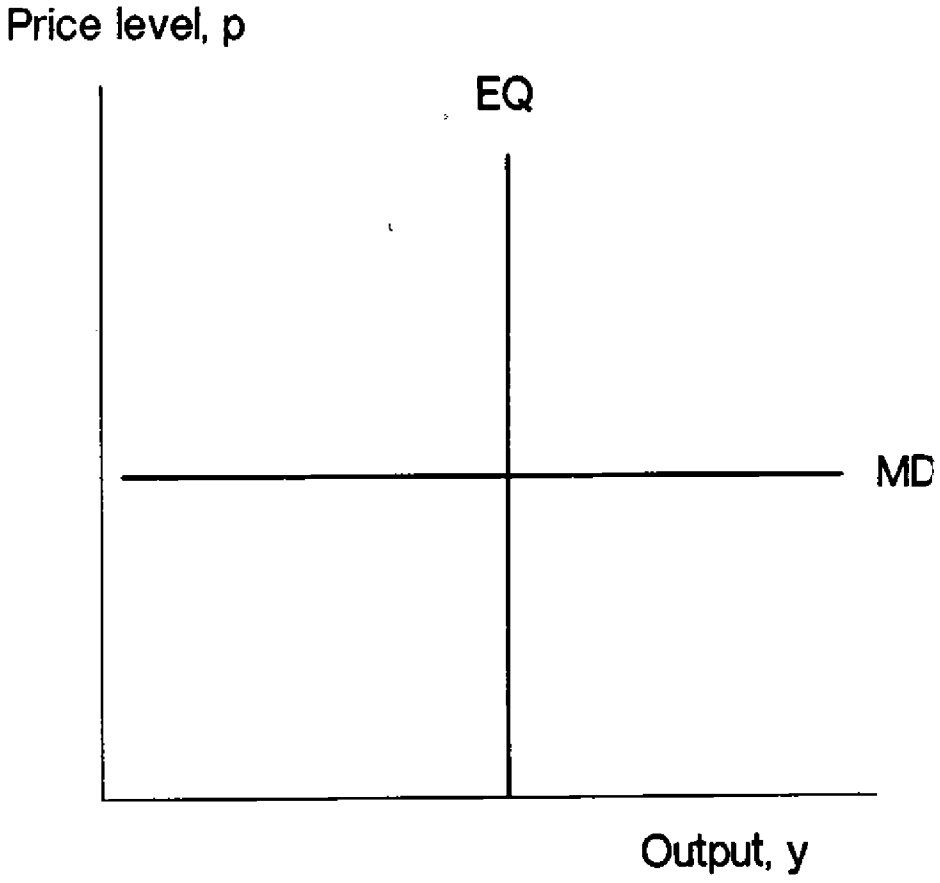
The share is α_0 when p is at a predetermined level, $\bar{p}$, and is higher when p is higher. People work harder and consume more when the price level rises. Standard macroeconomics would say the price level rises when output and employment are high, but it comes to the same thing.

The *EQ* schedule in this setup is

$$y = \frac{\alpha_0 \frac{p}{\bar{p}}}{1-\beta}(1-x) + x \tag{5.9}$$

It remains true that government purchases shift *EQ* to the right through an income effect. Putting in monetary non-neutrality does not eliminate the role of the variable that was important in

Figure 5-1. Equilibrium in the example



determining output in the case of full neutrality.

The MD curve is unchanged for the case of non-neutrality. Figure 5–2 shows the upward-sloping EQ schedule and flat MD schedules for the case. It shows that an increase in the quantity of money, M, will shift MD upward and raise output, thanks to the non-neutrality reflected in the slope of EQ.

6. *Intertemporal substitution*

Next I will consider a two-period version of the previous model with an explicit interest rate. Because there are no physical opportunities to trade between time periods, the real allocations in this model are the same as in the previous model. However, the existence of a credit market with an interest rate permits an interpretation of output movements as responses to the interest rate as well as income effects. Further, the new model serves as a full illustration of the derivation of the EQ and MD schedules.

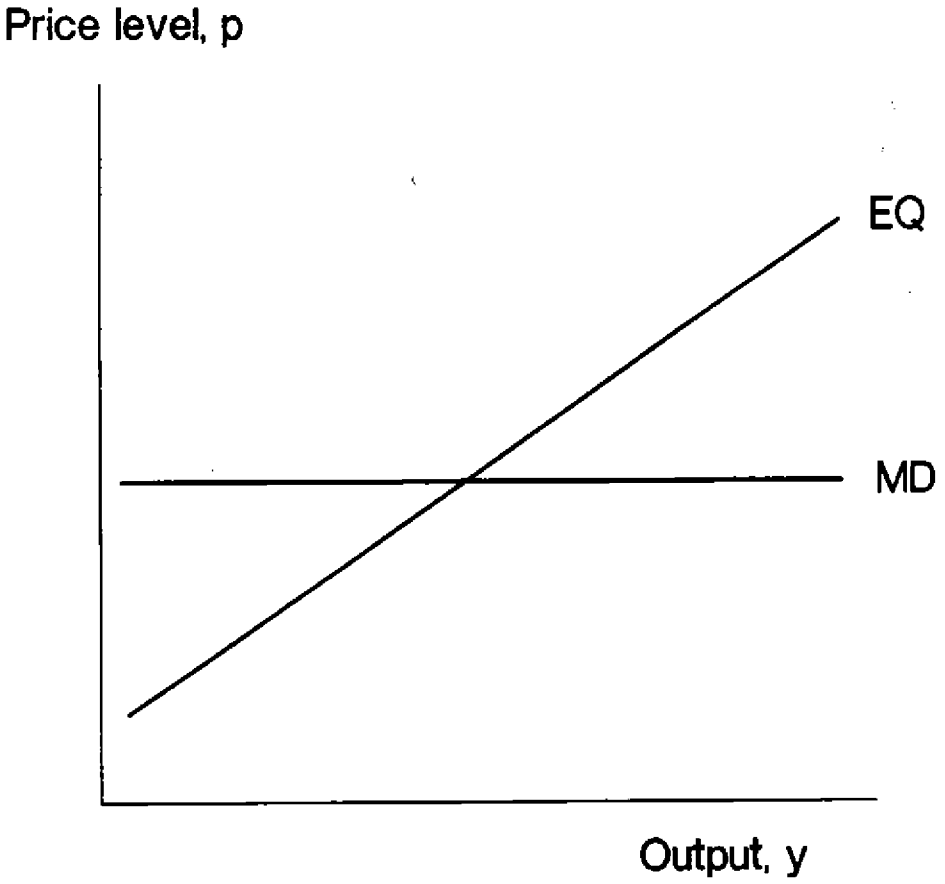
Let intertemporal utility be the sum over two periods of the log-utilities implicit in the previous model. Let R be the market discount rate: $R = 1/(1+r)$, where r is the interest rate. Then full wealth (the value of endowments at market prices) is

$$W(R) = 1 - x_1 + z_1 + R(1 - x_2 + z_2) \tag{6.1}$$

Solving as before for z yields

$$z = \tfrac{1}{2}\frac{\beta}{1-\beta}[1-x_1+R(1-x_2)] \tag{6.2}$$

Figure 5–2. Equilibrium in the 2nd example



Then full wealth is

$$z = \frac{1}{1-\beta}[1-x_1+R(1-x_2)] \tag{6.3}$$

The product demand schedule is

$$y = W(R) + x_1 \tag{6.4}$$

Demand is an increasing function of R, that is, a decreasing function of the real interest rate. The product-labor supply function is

$$y = 1 - \frac{1-\alpha-\beta}{2} W(R) \tag{6.5}$$

which is an increasing function of the real interest rate. The intersection of demand and supply is exactly as given earlier in equation 5.5. To derive the MD schedule, I start with the money demand function,

$$\mu\frac{M_1}{p_1} = \frac{\beta}{2} W(R) \tag{6.6}$$

Then I use the product demand schedule, equation 6.4, to replace W(R) by a function of y:

$$\mu\frac{M_1}{p_1} = \frac{\beta}{\alpha}(y_1-x_1) \tag{6.7}$$

or

$$p = \frac{\alpha\mu}{\beta} \frac{M_1}{y_1 - x_1} \tag{6.8}$$

Note that this version of MD has the customary downward slope, whereas the previous version was flat. Both versions intersect EQ at the same price level. This one contemplates the level of output that would be demanded if the interest rate were at a level that induced individuals to seek intertemporal trades, whereas in the earlier case, individuals were aware of the impossibility of such trades. In equilibrium no intertemporal trades occur, which is why the two MD curves intersect EQ at the same point.

Nonneutrality in product demand

In the following example, nonneutrality in product demand is a result of distributional effects from nominal precommitments. Firms agree in advance with their workers to provide a fixed nominal level of compensation, independent of the actual amount of work. That is, compensation is a guaranteed annual amount. The guarantee is in nominal terms because the parties view the monetary unit as the natural way to express forward obligations. Were monetary policy approximately optimal, nominal forward contracts would be correspondingly approximately optimal. The employment contract does not grant to employers the right to choose the level of employment without regard to the labor supply of the workforce. Rather, employment is set at the efficient level. The effect of the nominal precommitment is to make a lump-sum

transfer of wealth to management if the price level is unexpectedly high. Management places all incremental wealth in goods. Hence there is a distributional effect of the price level. A higher price level raises product demand through the assumption about management. It raises labor supply through a negative income effect. Hence a higher nominal price level raises equilibrium output. In the earlier model, there was exact proportionality between the nominal incomes of workers and the money stock. If contracts predetermine nominal incomes, then there is no freedom *ex post* for the money stock to differ from the level needed to ratify the predetermined income level. To get an interesting model, it is necessary to change the money demand assumption. A simple and standard assumption is that money is demanded in proportion to nominal GNP:

$$M = \theta py \tag{6.9}$$

Under this assumption, it is unnecessary to posit any rental earnings on money by the government. The consumption share of monetary services, β, is also taken as zero.

The derivation of equilibrium output is straightforward because the stabilization of compensation by management has the same effect in the model as the taxing and spending of the government. The government makes a lump-sum transfer from workers to itself and uses all of the proceeds to purchase goods. It is only necessary to link the level of the transfer, x, to the amount of the nominal compensation commitment. If the nominal commitment is $\bar{p}$, then it is $\bar{p}/p$ in real terms. Planned real compensation is α. Actual real compensation falls in proportion to

the excess of p over $\tilde{p}$. Thus the employer takes back x in real terms from the workers, where

$$x = \alpha(1 - \frac{\tilde{p}}{p}) \tag{6.10}$$

Recall that the EQ curve is

$$y = \alpha(1-x) + x \tag{6.11}$$

With the transfer, x, as in equation 6.10, the non-neutral EQ curve is

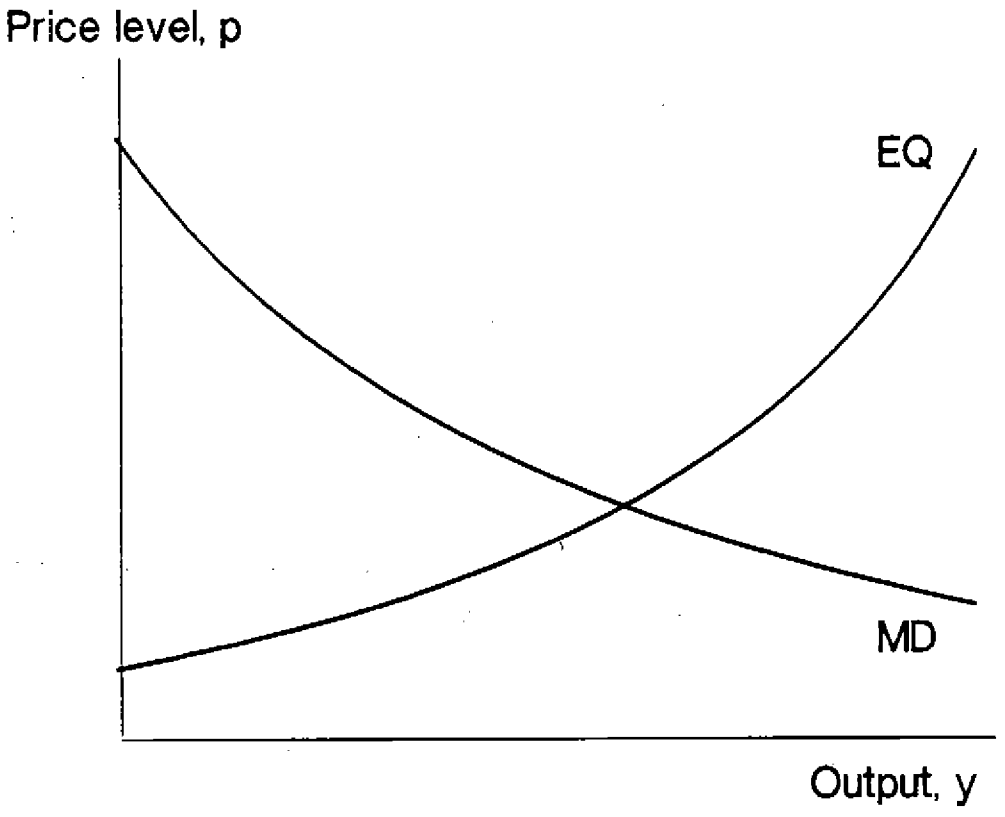
$$y = \alpha[1 + (1-\alpha)(1-\frac{\tilde{p}}{p})] \tag{6.12}$$

The MD curve is just a rewriting of equation 6.9:

$$y = \frac{M}{\theta p} \tag{6.13}$$

Figure 6−1 shows the upward-sloping EQ curve and the downward-sloping MD curve. An increase in M raises output. Again, the mechanism is distributional−an increase in nominal demand shifts the distribution of income toward managers, because of the nominal wage commitment. Managers place all of their earnings in goods, so there is a stimulus to goods demand, which raises equilibrium output just as an increase in government purchases would.

Figure 6-1. Nonneutrality in product demand



7. *Conclusions*

Models of the determination of equilibrium output need not lead separate lives from models of the short run, where nominal precommitments are important. Rather, nominal influences should be built into the product supply, product demand, and money demand functions of the equilibrium model. The resulting model can accommodate a wide spectrum of views about macroeconomics. At one end is the price-rigidity model, where sellers make call option contracts with their customers with nominal striking prices. In that model, the *EQ* curve simply describes the call option and is the same as the aggregate supply curve of standard expositions of price rigidity. At the other end is the real business cycle or pure equilibrium model with complete monetary neutrality. The analysis leading to the vertical EQ curve contains all the features of that model. The *EQ-MD* diagram shows how the price level is determined, an issue usually neglected in the real business cycle literature.

In between these two polar cases lies a wide variety of interesting macroeconomic models. The analysis of all types of noise in product or labor demand—government purchases, unpredictable agglomeration in the business sector, or shifts in consumer behavior—needs the full treatment underlying the *EQ* curve. The call-option hypothesis needed to justify the *AS* curve is too restrictive to describe the determination of total output, even if it is a helpful idea in understanding some sectors.

Analysis of monetary non-neutrality has been stagnant in recent years. The general framework outlined in this lecture calls attention to the great variety of ways that non-neutrality can enter

a macroeconomic model. In addition to call options with nominal striking prices in product and labor markets, nominal precommitments in bonds, mortgages, dividends, and long-term employment compensation generate important non-neutralities through distributional effects.

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