12 Aggregate Supply with Sticky Prices

Chapter 12 Contents

A. Topics and Tools

Part C of Romer's Chapter 6 examines four specific models based on the ideas of nominal and real rigidity. The first model (Section 6.9) is one of "predetermined price" contracts that is based on the kind of contracts introduced in a wage context by Fischer (1977). The "fixed-price" model of Section 6.10 uses a slightly different assumption about the nature of price setting to yield quite different macroeconomic dynamics. This model follows the contract structure used by Taylor (1979). Both the Fischer and Taylor models specify that prices are set for fixed periods of time, as happens with periodic wage negotiation or annual catalogs, so-called "time-dependent pricing." An alternative assumption, explored in Section 6.11, is "state-dependent pricing" in which prices are changed at possibly irregular intervals, depending on how far the established price is from the firm's desired price. Section 6.13

develops the Mankiw-Reis model, in which the firm's price changing interval is determined randomly. Mankiw and Reis (2002) hypothesize that such a model could result from the random arrival of information to any given firm about the underlying inflation rate in the economy.

B. Understanding Romer's Chapter 6, Part C

Part B of Romer's chapter examined the incentives of each individual firm in deciding whether to change its price or keep it fixed. In Part C, we embed these firms into a macroeconomic model and consider the macroeconomic implications of price stickiness.

Romer's "building blocks"

Romer begins in Section 6.8 by developing a dynamic version of the imperfect competition model of Section 6.4. This model is based on utility maximization by households and profit maximization by firms, so its microfoundations are quite completely developed. Most of the elements of this model are familiar, but some take slightly new forms.

For example, the utility function (6.59) is a discrete-time lifetime utility function similar to ones we used in the Diamond growth model and the real-business-cycle model. Utility is an "additively separable" sum of utility from consumption and disutility from labor. The additivity of the utility function simplifies the analysis by making the marginal utility of consumption independent of labor and vice versa. The condition $V' > 0$ means that more work leads to more disutility (working is disliked), and $V'' > 0$ implies that the more you work, the greater is the marginal disutility of work. These conditions are the flip-side of an assumption that leisure has positive but diminishing marginal utility.

The discount factor in equation (6.59) is written simply as $\beta \in (0,1)$. In earlier chapters we wrote the discount factor as $1/(1+\rho)$, where ρ is the marginal rate of time preference. You can think of β as equal to $1/(1+\rho)$ if you wish; it is just a more compact notation.

Equation (6.61) is the first-order condition relating to the trade-off between consumption at time t and labor at time t. It says that the marginal disutility of working (the left-hand side) must equal the marginal utility of the goods that can be bought with an additional unit of work (the right-hand side).

The new Keynesian *IS* curve in equation (6.65) follows directly from the consumption Euler equation in log form. As with traditional *IS* curves, it slopes downward in (Y, r) space. This relationship between Y and r depends on future Y, which is quite different than the traditional *IS* curve, which depended on fiscal policy.[1]

The theory of the firm in the discussion on pages 312 through 314 is a little tricky. We usually simply assume that each firm maximizes the present value of its stream of profits. Here, the firm is assumed to maximize the *utility* of its stream of profits to the shareholders. With a competitive credit market, these assumptions are equivalent. To see this, consider Romer's equation (2.47) in the discussion of the Diamond model on page 78. This equation applies to the equilibrium between consumption in periods 1 and 2. Solving it for $1 + r_{t+1}$ yields

$$1+r_{t+1} = (1+\rho)\frac{C_{2,t+1}^{\theta}}{C_{1,t}^{\theta}} = (1+\rho)\frac{C_{1,t}^{-\theta}}{C_{2,t+1}^{-\theta}} = (1+\rho)\frac{U'(C_{1,t})}{U'(C_{2,t+1})}. \tag{1}$$

The right-hand equality in equation (1) follows directly from the definition of the utility function. In the Diamond model, individuals live for only two periods, so the only relevant comparison is between t and $t + 1$.

The owners of firms in the new Keynesian model are longer-lived, so we must also consider consumption tradeoffs between more distant points in time. If we were to generalize equation (1) to reflect the tradeoff between consumption at time zero and time t, the corresponding equation would be

$$1+\overline{r}_t \equiv \prod_{s=1}^{t}(1+r_s) = (1+\rho)^t \frac{U'(C_0)}{U'(C_t)}. \tag{2}$$

Taking the reciprocals of both sides of equation (2) yields

$$\frac{1}{1+\overline{r}_t} = \left(\frac{1}{1+\rho}\right)^t \frac{U'(C_t)}{U'(C_0)}. \tag{3}$$

If, as we suggested above, the discount factor β can be thought of as $1/(1 + \rho)$, then we can rewrite (3) as

$$\frac{1}{1+\overline{r}_t} = \beta^t \frac{U'(C_t)}{U'(C_0)} = \lambda_t. \tag{4}$$

[1] It is clear that changes in expected future income would affect the traditional *IS* curve as well, however, if we consider that consumption would surely be affected. The traditional curve just does not model this explicitly.

This λ_t term is defined by Romer in text in the paragraph below equation (6.66). From the derivation above, we can see that it serves the same role as the usual discount factor involving the interest rate. In particular, if the interest rate were constant between time 0 and time t, equation (4) would simplify to

$$\left(\frac{1}{1+r}\right)^t = \beta^t \frac{U'(C_t)}{U'(C_0)} = \lambda_t. \tag{5}$$

Thus, the λ_t term in equation (6.67) can be interpreted as a discount factor in which the equilibrium interest rate from the consumption side of the model has been substituted in.

Another potentially confusing component of equation (6.67) is π_t, which here does not denote profits or inflation but rather the probability that a price set today has not been changed t periods later. This probability depends on the firm's future decisions about whether or not to change price—the decisions we analyzed in the previous section. In the remaining sections of Chapter 6, Romer looks at several alternative models for π_t, including time-dependent models in which the pattern of price-changing is exogenous (as with fixed-length contracts) and state-dependent models in which the decision to change prices depends on economic conditions. For now, we simply treat π_t as a parameter, leaving its determination unspecified.

This leads us to Romer's maximand shown in equation (6.67), which is more complex than it appears because of uncertainty. By making a couple of reasonable simplifying assumptions and using a second-order Taylor series approximation to the effect of prices on profits, he arrives at equation (6.72), which has a useful intuitive interpretation.

To understand this equation you need to be very clear about what p_i and p_t^* represent. The price p_i is the price that the firm sets now, knowing that it will be in place both in the current period and (probably) in some future periods. The price p_t^* is the price that would be ideal for the firm to set in period t if it were to set the price independently for each period.

Equation (6.72) shows that the firm should set a price now that equals the average of the ideal prices in each future period, weighted in proportion to the probability that the current price will still be in effect during that future period. For example, if it is known that the newly set price will be in effect for two periods, then the optimal price for the firm to set is the (unweighted) average between the desired price in the first period and the desired price in the second period. If the new price will be in effect for the first period and there is a 50% chance it will be in effect for the second period (but not any longer), then the firm should set the price at a weighted average of the two ideal prices with a 2/3 weight given to the current period and a 1/3 weight to the second.

Equation (6.72) and its certainty-equivalent form (6.73) are central to the dynamic new Keynesian model. They describe the solution to a basic problem: how to set a price that will carry over into future time periods. The solution is a logical one: set a price that is the average of the prices you'll want in the future.

The final piece of the puzzle in this section is the somewhat cryptic paragraph at the top of page 314. He asserts that the "profit-maximizing real price is proportional to the real wage." If we can set a distinct price for period t, then we would want to maximize R_t in equation (6.66). We can derive Romer's result easily by maximizing equation (6.66) with respect to (P_{it}/P) and setting the result equal to zero:

$$\frac{dR_t}{d\left(P_{it}/P\right)} = Y_t\left[\left(1-\eta\right)\left(\frac{P_{it}}{P}\right)^{-\eta} + \eta\frac{W_t}{P_t}\left(\frac{P_{it}}{P}\right)^{-\eta-1}\right]. \tag{6}$$

The derivative in (6) can equal zero only if the bracketed expression is zero, which implies

$$\left(1-\eta\right)\left(\frac{P_{it}}{P}\right)^{-\eta} = -\eta\frac{W_t}{P_t}\left(\frac{P_{it}}{P}\right)^{-\eta-1}$$

or

$$\frac{P_{it}}{P} = \frac{\eta}{\eta-1}\frac{W_t}{P_t}. \tag{7}$$

Equation (7), which is identical to Romer's equation (6.40), demonstrates the assertion that the desired price is proportional to the real wage.

To show how the remainder of the paragraph follows, suppose that (as suggested in footnote 31) $V(L)$ in the utility function is aL^{γ}. Substituting for V' in Romer's equation (6.61) yields

$$\frac{W_t}{P_t} = \frac{a\gamma L_t^{\gamma-1}}{C_t^{-\theta}} = a\gamma Y_t^{\gamma+\theta-1}. \tag{8}$$

Plugging (8) into (7) yields

$$\frac{P_{it}}{P} = \frac{a\gamma\eta}{\eta-1}Y_t^{\gamma+\theta-1},$$

or in log terms,

$$p_{it} - p_t = \ln\left(\frac{a\lambda\eta}{\eta - 1}\right) + (\gamma + \theta - 1) y_t. \tag{9}$$

This corresponds to Romer's equation for p^* in text above equation (6.74), with $c = \ln[a\lambda\eta/(\eta - 1)]$ and $\phi = (\gamma + \theta - 1)$. Obviously, $c \neq 0$ in general. However, Romer is correct in saying that setting $c = 0$ does not change the fundamental result and keeps the algebra simple. (Warning: Some past macro students have been asked to show this on a take-home exam.)

Romer's equations (6.74) and (6.75) give us the "building blocks" we need in order to proceed with the analysis of macro models with sticky prices. All that remains is to specify the pattern of price stickiness. Romer considers the four basic patterns of price stickiness shown in Table 1. Romer has adapted each of these models in simplified form using common notation. This means that Romer's versions of these models do not correspond exactly to the versions in the original sources. However, the basic conclusions of the models are representative of those of the more widely varying models in the literature.

The predetermined-price model is a cousin of the wage-contract model developed in a seminal paper by Stanley Fischer (1977). In this model, prices are set for two periods at a time, with half of the firms in the economy setting their prices in even periods and the other half in odd periods. The price a firm sets for the first of the two periods is not necessarily the same as the price set for the second. Romer calls this model the "predetermined-price" model. He shows that monetary policy can have a positive countercyclical role under these assumptions (as in Fischer's original wage-contract model). Monetary shocks have real effects that last two periods.

Table 1. Classification of price-setting regimes under imperfect competition.

Model	Section	Description
Predetermined prices (Fischer)	6.9	Prices set for two periods at a time. May set a different price for first and second periods.
Fixed prices (Taylor)	6.10	Prices set for two periods. Same price must be set for both periods of contract.
Caplin-Spulber	6.11	Models how firms decide when to change prices in simple, constant inflation setting.
Mankiw-Reis	6.13	Like predetermined prices except firms set prices when they receive new macroeconomic information, which happens randomly with probability α per period.

Model number two is based on another wage-contract model originally due to John Taylor (1979). Romer calls this the "fixed-price" model. This model also has overlapping price setting for two periods at a time. It differs from the predetermined-price model in that firms are constrained to set the *same* price for the two periods rather than a different price for the first and second periods of the "contract." This model has similar implications for monetary policy, but leads to quite a different dynamic response to a monetary shock. In the predetermined-price model, monetary effects lasted only as long as the longest price contract (two periods). In the fixed-price case, the real effects of the monetary shock are longer lasting, damping out to zero only asymptotically.

The third model allows the frequency of price change to be determined by the agent's need to change prices, rather than according to a strict and exogenous schedule. In the Caplin-Spulber model, agents adjust prices when the gap between their existing price and their optimal price becomes large enough. While Romer does not present all of the underlying logic to justify this behavior, he does use this model to show that money can be neutral under sticky prices.

The final model is a more recent one developed by Mankiw and Reis (2002). In this model, firms set a pricing policy for the indeterminate future based on their current information. As in the predetermined price model, they may set a different level of price for each period, so for example they may set a policy of increasing price by 2% each year indefinitely. A randomly selected share α of firms receives new macroeconomic information each period and, when they receive new information, reformulates strategies. In this model, the adjustment costs do not result from changing prices but rather from acquiring detailed macroeconomic information and reformulating a dynamic pricing policy.

Macroeconomic equilibrium with predetermined prices

As described in Table 1, agents in the predetermined-price model set prices in advance for each of the next two periods. The reasons for this price stickiness are not addressed until later, but one can most easily think of this price stickiness as fixed-term contracts that are established every two periods.

Romer adopts the (potentially confusing) notation that p_t^1 is the price set for period t by the half of the people who set prices at the end of period $t-1$ and p_t^2 is the period t price set by the other half of the economy who established their prices at the end of period $t-2$. The superscripts here *are not exponents*, so do not think of the p^2 term as a square. Once you get the notation down, the algebra on pages 317 and 318 should be pretty easy to understand.

The ***law of iterated projections*** at the bottom of page 317 warrants some discussion. What this law says is that your current (2009) expectation of the price that will prevail in the year 2011 cannot be different than your current (2009) expectation of the price that you will expect in 2010 to prevail in 2011. If you have rational expectations, then your expectation of the 2011 price will only change from 2009 to 2010 due to *new* information that becomes available in 2010. Since you do not, by definition, have that information now, you cannot anticipate how your expectation will change and $E_{2009}[E_{2010}[P_{2011}]] = E_{2009}[P_{2011}]$.[2]

The solution of the model is summarized by equations (6.84) and (6.85). The former shows that the price level in period t depends on the expectations of the period t money supply during the two periods in which the prices for the current period were set ($t - 2$ and $t - 1$). The latter shows that the deviation of output from its steady-state value (by normalization, this value is one, or zero in log terms) is due to two "money-surprise" terms. The first of these measures the change in the prediction about the current money supply based on information that arrived last period; the latter is the deviation of the current money supply from what was expected last period.

Romer describes two key implications of these results. The first is that, in contrast to Lucas's model, there is a positive role for countercyclical monetary policy here. Shocks that are one period old still affect real output (through $E_{t-1}m_t - E_{t-2}m_t$). The central bank can observe these shocks and respond by changing the money supply in period t. This monetary-policy reaction is a change in $m_t - E_{t-1}m_t$ that brings y_t back to its steady-state level (zero).

The second key result is that a modified version of monetary neutrality continues to hold in this model. Changes in the money supply that people know about more than two periods in advance have a proportional effect on prices and no effect on output. Consider the effect of an unexpected, one-time, permanent increase in the money supply happening at date t. This will affect output in t and $t + 1$, but from periods $t + 2$ onward, prices will be proportionately higher and output will be unaffected by the shock. Thus, the non-neutrality of money in this model has a finite lifetime equal to the length of the "contract"—the longest amount of time in advance that prices are set.

Macroeconomic equilibrium with "fixed" prices

Romer's third model of this section is based on Taylor's overlapping wage-contract model. As in the case of the Fischer model, Romer adapts the model to look at overlapping price setting rather than wage-setting, and to do so must take explicit account of imperfect competition in the product market.

It is important to keep in mind the difference between "fixed" and "predetermined" prices as Romer uses the terms. In each case, firms set prices for two-period intervals, with half of the firms setting prices in even-numbered periods and half in odd-numbered periods. However, in the fixed-price model, the firms must decide on a single level of price to prevail in both of the upcoming periods. With predetermined

[2] For a detailed mathematical discussion of the law of iterated projections, see Sargent (1987), Chapter X, Section 3.

prices they are able to specify a different price for the first and second periods. This seemingly minor alteration of the price-setting structure has a substantial effect on the dynamic behavior of the model.

Equation (6.89) shows that firms setting prices today (for the next two periods) set a price that is based on the average of the price set last period and their expectations of the price to be set next period, along with the current money supply. To understand the rationale for this, think about the markets in which the currently set price x_t will prevail. During the first period, firms setting x_t will be competing with firms who set prices last period at x_{t-1}. Since the other half of the market has a preset price of x_{t-1}, firms will not want to deviate too much from this price lest they lose too much of the market (if $x_t > x_{t-1}$) or fail to take advantage of profit opportunities afforded by their competitors' overpricing (if $x_t < x_{t-1}$). Similarly, during the second period that the price currently being set will be in effect, it will be competing against the price to be set next period, about which our current expectation is $E_t\,[x_{t+1}]$. For similar reasons, they would like to keep x_t fairly close to $E_t\,[x_{t+1}]$.

Thus, over the two periods, the average price against which we expect the currently set price to compete is the average of x_{t-1} and $E_t\,[x_{t+1}]$, which is the first part of (6.89). The second part shows the effect of the optimal long-run price, which under our simple normalization is m_t. In long-run equilibrium with no monetary shocks, $x_t = x_{t-1} = E_t\,[x_{t+1}] = m_t$, which shows that money is neutral in the long run in this model.

The method of undetermined coefficients, which Romer uses to solve the fixed-price model, may be familiar to you from the real-business-cycle chapter. We posit a hypothetical solution such as (6.90), then use the properties of the model to demonstrate the correspondence between the parameters of the solution (μ, λ, and ν) and the parameters of the original model (in this case, just ϕ). The mathematical derivation carried through to equation (6.101) executes this procedure.

The only difficult aspect of this derivation is the fact that the equation for λ in terms of ϕ is quadratic, which means that there are two different values of λ that solve the model. Romer notes that one value is greater than one and the other is less than one in absolute value, and that only the value that is less than one leads to a stable equilibrium. The use of stability to choose which of two possible roots is appropriate for equilibrium is an extension of ***Samuelson's correspondence principle***, which argues that because equilibrium in the actual economy is stable rather than explosive, we are justified in ignoring possible parameter values that lead to explosive behavior.

The fixed-price model implies that monetary shocks will have long-lived effects on output. Instead of the truncated impact of the predetermined-price model, where output is affected for a finite number of periods, the effects of a monetary shock in this model will die away gradually, converging on neutrality only asymptotically.

The relationship between the mean lag in the effect of monetary policy and the length of the contract is called the "contract multiplier." Since inflation and output fluctuations are more persistent than our models often predict, the contract multiplier in a Taylor-type model has been proposed as a potential explanation.[3]

While lag operators are extremely useful for many tasks in time-series analysis, they are not crucial here. It does not seem worth your time to read and learn the material about them on pages 323–326, so you may skip this section.

Evaluation of the Fischer and Taylor models

The Fischer and Taylor models were criticized on several grounds. One was the ad-hoc nature of the length of the price (wage) contract. Why should agents set prices or wages for two periods rather than one, when utility would be higher if they set them in each period? Another case of $50 bills lying on the sidewalk?

A considerable literature on the optimal length of contracts ensued.[4] Models of contract length commonly assume that there are fixed negotiation costs that must be incurred each time a contract is negotiated (or the price is set, in our context). Because of these fixed costs, agents will fix prices/wages for a finite contract period. The length of the contract period is determined by striking a balance between the disequilibrium costs of being away from the optimal price or wage (which rises with longer contracts) and the per-period negotiation cost (which rises with shorter contracts).

Another common criticism was that the models exclude the possibility of ***indexed contracts,*** which would allow prices or wages to respond fully to monetary changes and thus eliminate the source of non-neutrality in the model. An indexed contract could make the price or wage a function of the money supply, similar to cost-of-living adjustments based on the actual CPI. With appropriately indexed contracts, markets would always clear. This means that indexed contracts would lead to welfare gains, so agents would have a strong incentive to use them rather than the predetermined-price or fixed-price arrangements that are assumed by Fischer and Taylor. Although this was an important criticism, other economists argued that in the labor-market context, indexed contracts might have to be unreasonably complex in order to fully offset changes in the money supply. It might be difficult to design indexing rules that would allow for both monetary shocks and also changes in productivity or in the relative demand for the product.

Ultimately, the most damning evidence against the Fischer and Taylor wage-contract models (which does not apply to the price-based versions in Romer) was that both models rely on strongly countercyclical real wages to produce their basic

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[3] For example, see Chari, Kehoe, and McGrattan (2000).

[4] An excellent and quite readable paper is Gray (1978).

results. In both cases, a contract wage that turns out to be too high, given the price level that ends up prevailing in the period, leads to a high real wage that causes firms to reduce employment and output and leads to a recession. Since real wages seem to be mildly procyclical rather than strongly countercyclical, these models have lost much of their initial popularity.

The Caplin-Spulber model

The Caplin-Spulber model differs from the Fischer and Taylor models in that there is no fixed frequency at which prices are set. Instead, agents change prices when their desired price gets far enough from their existing price. This is an example of ***state-dependent*** rather than ***time-dependent*** pricing. Under certain quite restrictive assumptions, one can show that the *Ss* pricing rule of the Caplin-Spulber model is optimal. (See the citations in Romer.) In particular, the model is usually applied to a situation of steady inflation of the general (average) price level.[5]

Under an *Ss* rule, firms keep prices constant until the difference between actual and desired price reaches some trigger threshold *s*, then they reset the price. However, they do not reset the price to the *current* desired price because that price will be out of date an instant later. Instead, they overshoot their current desired price and set the price *S* units above it. As inflation continues, their fixed price gradually falls in relation to the desired price, which rises with the general price level in the economy. Eventually, their relative price falls to *s*, at which point another price increase is triggered.

You can think of the dynamic behavior of a single firm's price in the *Ss* model as being a step function of time that moves above and below an upward-sloping line, which represents the steady increase in the desired price. When the desired-price line gets far enough above the previous step, the agent raises price and leaps above the line, staying there until the desired-price line catches up and again moves far enough above.

Interestingly, money is neutral in the Caplin-Spulber model because an unusually large increase in the money supply pushes more firms above the price-adjustment threshold. Although each firm's price is fixed for a finite period of time, as in Romer's variants of the Fischer and Taylor models, the *aggregate* price level is perfectly flexible. This comes about because the length of the price contract is endogenous. A monetary shock makes it more or less desirable to change prices, thus causing the average price level to respond directly to the shock.

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[5] Recent papers have applied state-dependent models using simulation techniques to get around the complexity that precludes analytic solution in all but simple cases. See Dotsey, King, and Wolman (1999), Dotsey and King (2005), and Caballero and Engel (2007).

Mankiw and Reis: sticky information vs. sticky prices

Mankiw and Reis (2002) present a model that attempts to "correct" several implications of the new Keynesian Phillips curve that are both counterintuitive and counterfactual. Romer discusses the problem of *inflation inertia* at the end of Section 6.12. However, this is only one of three problems that Mankiw and Reis discuss and try to solve in their paper. They also consider the counterfactual implication of some sticky-price models that a credible disinflation (reduction in inflation) can be expansionary and the discrepancy between the speed of adjustment of inflation to changes in monetary policy between the implications of sticky-price models and the empirical evidence.

Laurence Ball (1994) looks carefully at the implications of a simple sticky-price model for sudden disinflations. He finds that while a credible *deflation*, in which the central bank lowers the money supply over time and prices must fall, leads to the expected recession, a credible *disinflation*, in which the central bank reduces the *rate of growth of the money supply* from a positive value to zero, leads not only to no recession but actually causes output to be above full employment.

Ball explains the intuition of the difference between the effects of deflation and disinflation as follows:

> To understand the difference between deflation and disinflation, recall why the former reduces output: prices set before deflation is announced are too high once money begins to fall. In the case of disinflation, the overhang of preset prices is a less serious problem. Prices set before an announcement of disinflation are set higher than the current money stock in anticipation of further increases in money. … However, the overhang of high prices is easily overcome if money growth, while falling, remains positive for some time. The level of money quickly catches up to the highest preset price and can then be stabilized costlessly. (Ball 1994, 286–287)

Essentially, *price* stickiness does not imply *inflation* stickiness, which means that a reduction in money *growth* has different effects than a change in the *level* of the money supply.

Fuhrer and Moore (1995) argue that the sticky price model implies no persistence in inflation, whereas the data indicate that the autocorrelations of the inflation rate are quite high. Again, it is prices that are sticky in the theoretical model, whereas the data seem to indicate stickiness of inflation.

Finally, Mankiw (2001) compares the theoretical time-path of the response of inflation to changes in money growth to econometrically estimated responses. He finds that sticky-price theory suggests that inflation should adjust quickly to changes in money growth, but the evidence suggests that adjustment is slow.

Mankiw and Reis replace the assumption of sticky prices with one of "sticky information." Because it is information that is sticky rather than prices, this model introduces stickiness or persistence into *inflation*. They do this by restricting the frequency with which firms can adopt new pricing strategies.

In each period, a fraction α of firms receives current macroeconomic information and updates its pricing strategy and the remaining fraction $(1 - \alpha)$ keeps its old pricing policy intact. Thus, α share of firms are setting their price at the level that is currently optimal and $(1 - \alpha)$ are using older information. Similarly, in the previous period, α share had the opportunity to reset pricing policy and $(1 - \alpha)$ did not, so the share $(1 - \alpha)^2$ are using information more than one period old. Following the same logic, $(1 - \alpha)^i$ is the share of firms whose information and pricing policies are at least i periods old and $1 - (1 - \alpha)^i = \lambda_i$ is the fraction that has updated less than i periods ago.

The algebra of the remainder of the last paragraph on page 335 is complex, but the logic is straightforward. By obtaining the expression for a in equation (6.121), Romer solves for the equilibrium output expression using (6.118). This expression shows that output is a function of monetary policy shocks extending back into the indefinite past.

The Mankiw-Reis model exhibits considerable inflation persistence due to the interaction of nominal and real rigidity. The persistence is in inflation rates rather than price levels because of the predetermined-price nature of the individual pricing policies that firms adopt. Moreover, simulations in the Mankiw and Reis (2002) show that the model can lead to a delayed reaction to monetary policy in which the maximum effect of policy changes on output do not occur immediately.

In a more recent follow-up to their 2002 paper, Mankiw and Reis (2006) examine the ability of macro models to reproduce three stylized facts about modern business cycles: (1) inflation rises when output is above its trend level, (2) real wages are smoother than labor productivity, and (3) most real variables have gradual, hump-shaped responses to shocks.

They find that in order to explain these three phenomena, more than simply sticky information of price setters is required. They introduce additional information stickiness (or "inattentiveness") in household consumption planning in workers' labor supply decisions. Only if all three forms of inattentiveness are present in the model can the three stylized facts all be explained.

C. Suggestions for Further Reading

Original papers on wage-contracting models

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Karni, Edi, "On Optimal Wage Indexation," *Journal of Political Economy* 91(2), April 1983, 282-92.

Blanchard, Olivier, "Wage Indexing Rules and the Behavior of the Economy," *Journal of Political Economy* 87(4), August 1979, 798-815.

Vroman, Susan B., "Inflation Uncertainty and Contract Duration," *Review of Economics and Statistics* 71(4), November 1989, 677-81.

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Akerlof, George A., and Janet L. Yellen, "A Near-Rational Model of the Business Cycle, with Wage and Price Inertia," *Quarterly Journal of Economics* 100(Supplement), 1985, 823–838.

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