A Theory of Economic Slack

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Draft version: June 2026
Draft URL: pascalmichaillat.org/18/

CHAPTER 16.

From unsold goods to unemployed workers

Chapter 13 showed that the US unemployment gap is generally positive and sharply countercyclical. The aim of part IV is to explain which aggregate shocks can generate these fluctuations, and to clarify how monetary and fiscal policy can undo such shocks so as to stabilize unemployment fluctuations.

In chapter 14, we developed the simplest possible slackish business cycle model to answer these questions. The main limitation of that chapter, however, is that it does not feature firms. All workers are self-employed and sell their production directly to other households. This is not very realistic as in the modern US economy, most production is mediated by firms, and only about 10% of the labor force is self-employed (Katz and Krueger 2019, table 1). To improve the realism of the slackish business cycle model, this chapter extends it by introducing firms that hire their employees on a labor market and sell their production on a product market.

This chapter's model therefore features two markets and two types of slack: a labor market with unemployed job seekers and a product market with unsold services and therefore idle workers. Both labor and product markets are organized around a matching function and are dynamic, as in the model of chapter 14. Just as workers and firms are in long-term employment relationships, consumers and firms are in long-term customer relationships. In that way, product and labor markets are perfectly symmetric.[1]

[1] Okun (1981, p. 142) also thought that the labor and product markets should be treated symmetrically. He argued that "In [many respects], customer markets share the characteristics of career labor markets. Both feature search costs, information costs, and bilateral-monopoly surpluses associated with established relations."

Critically, product market slack and labor market slack interact with each other, thus providing a richer description of the labor demand. For instance, after an increase in aggregate demand, firms find more customers. This reduces the idle time of firms' employees and thus increases firms' labor demand. This in turn reduces unemployment. This richer labor demand allows us to answer many new questions that we could not address in the labor market model of chapter 11. We examine how aggregate demand shocks influence the labor demand, how they can be distinguished from technology shocks that also influence the labor demand, and how monetary policy stimulates labor demand by boosting aggregate demand.

Another advantage of the two-market structure is that the model now displays the structure that is typical of modern business cycle models: a product market and a labor market, with firms hiring labor in one and selling production in the other, and households supplying labor in one and consuming products in the other. It is therefore easier to compare this slackish business cycle model to other business cycle models, such as the Real Business Cycle model or New Keynesian model, as we do in chapter 22.

16.1. Overview of the model

This chapter brings together several model blocks developed in the previous chapters, and uses them to build a complete business cycle model with households, firms, a product market, and a labor market.

These markets are both organized around a matching function. Instead of having one big market where services are directly sold and all households are self-employed, we have two different markets and introduce firms in the model that transform labor into goods and services. We keep the same notation on the product market and labor market, using only a subscript to designate the market (table 16.1).

First, households participate in the labor force, which generates a supply curve on the labor market, as in chapter 11.

Second, firms decide how many workers to hire, based on how easy it is to sell on the product market and how easy it is to recruit on the labor market. Firms' decisions generate the demand curve on the labor market, which is an extension of the labor demand in chapter 11. The labor demand depends on both product market tightness and labor market tightness; it therefore connects the two markets together.

Third, firms use labor to produce goods and services that they sell to households on the product market. For simplicity, we assume that just like services, goods cannot be stored, so unsold goods perish immediately. Firms' production capacity determines the aggregate supply, which constitutes the supply curve on the product market. The aggregate supply is an extension of the aggregate supply in chapter 14.

Fourth, households' decisions to spend or save determine the aggregate demand, which constitutes the demand curve on the product market. The aggregate demand takes the same form as in chapter 14.

Finally, the model features 4 equilibrating variables—2 per market. On the product market, the equilibrating variables are the product market tightness, which determines how easy or hard it is to buy and sell products, and the real interest rate, which determines the price of products relative to government bonds. On the labor market, the equilibrating variables are the labor market tightness, which determines how easy or hard it is to find jobs and employees, and the real wage, which determines the price of labor relative to products.

For simplicity, and following the assumption made in chapters 11 and 14, we assume that the real wage w is fixed, determined by a wage norm, and price inflation π is fixed, determined by an inflation norm. The central bank determines the real interest rate r, which with fixed inflation is tantamount to determining the nominal interest rate.

16.2. Building blocks of the model

In this section we collect the different building blocks of the model. Because all firms and households are the same, and because by now the distinction between individual and aggregate variables is hopefully clear, we directly use a representative household and representative firm to describe and solve the model.

16.2.1. Equilibrium labor supply

The equilibrium labor supply is the same as in chapter 11. The labor supply is an equilibrium object as it assumes that flows are balanced on the labor market. The equilibrium labor supply is the employment level given the labor force participation and labor market flows:

$$l^s(\theta_l) = [1 - u_l(\theta_l)]\, h, \tag{16.1}$$

where $h > 0$ is the size of the labor force, θ_l is the labor market tightness, and $u_l(\theta_l)$ is the equilibrium slack rate on the labor market—the equilibrium unemployment rate—given by

$$u_l(\theta_l) = \frac{\lambda_l}{\lambda_l + f_l(\theta_l)}. \tag{16.2}$$

In the expression for the unemployment rate, λ_l is the job separation rate, and $f_l(\theta_l) = m_l(1, \theta_l)$ is the job finding rate, itself determined by the labor market matching function $m_l(U_l, V_l)$.

TABLE 16.1. Notation in the slackish business cycle model with two markets

Product market			Labor market		
Symbol	Name	Definition	Symbol	Name	Definition
k	Aggregate capacity	–	h	Labor force	–
V_p	Shop visits	–	V_l	Job vacancies	–
U_p	Unsold goods and services	–	U_l	Unemployed workers	–
v_p	Visit rate	$v_p = V_p/k$	v_l	Vacancy rate	$v_l = V_l/h$
u_p	Idleness rate	$u_p = U_p/k$	u_l	Unemployment rate	$u_l = U_l/h$
$m_p(u_p, v_p)$	Matching function	–	$m_l(u_l, v_l)$	Matching function	–
θ_p	Product market tightness	$\theta_p = v_p/u_p$	θ_l	Labor market tightness	$\theta_l = v_l/u_l$
f_p	Selling rate	(4.4)	f_l	Job-finding rate	(4.4)
q_p	Buying rate	(4.5)	q_l	Job-filling rate	(4.5)
κ_p	Matching cost	–	κ_l	Recruiting cost	–
τ_p	Matching wedge	(9.13)	τ_l	Recruiting wedge	(11.4)
y	Output	–	l	Employment	–
y^s	Aggregate supply	–	l^s	Labor supply	–
y^d	Aggregate demand	–	l^d	Labor demand	–
c	Consumption	–	n	Producers	–
$\mathcal{U}$	Utility function	(14.2)	$\mathcal{Y}$	Production function	(11.5)
a_p	Taste for consumption relative to saving	–	a_l	Labor productivity	–
α_p	Diminishing marginal utility of consumption	–	α_l	Diminishing marginal productivity of labor	–
λ_p	Consumer-producer separation rate	–	λ_l	Employer-employee separation rate	–
p	Price	–	w	Nominal wage	–

16.2.2. Equilibrium labor demand

The equilibrium labor demand is almost the same as in chapter 11, but it must be extended to capture the fact that not all goods and services offered for sale on the product market by the firm are actually sold. The labor demand is an equilibrium object as it assumes that flows are balanced on the labor and product markets.

Because the product market is slackish, only a share $1 - u_p(\theta_p)$ of goods and services are sold at any point in time, where θ_p is the product market tightness and u_p is the equilibrium slack rate on the product market, given by

$$u_p(\theta_p) = \frac{\lambda_p}{\lambda_p + f_p(\theta_p)}. \tag{16.3}$$

In the expression for the slack rate, λ_p is the customer-producer separation rate, and $f_p(\theta_p) = m_p(1, \theta_p)$ is the customer finding rate, itself determined by the product market matching function $m_p(U_p, V_p)$.

As a result, although the firm production function remains concave and given by

$$k(n) = a_l \cdot n^{1-\alpha_l}, \tag{16.4}$$

the flow of real profits is modified to

$$\mathcal{P} = \left[1 - u_p(\theta_p)\right] k(n) - w\left[1 + \tau_l(\theta_l)\right] n, \tag{16.5}$$

where w is the real wage, n is the number of producers in the firm, $k(n)$ is the firm's production capacity, θ_l is the labor market tightness, and τ_l is the equilibrium recruiting wedge, given by

$$\tau_l(\theta_l) = \frac{\kappa_l \lambda_l}{q_l(\theta_l) - \kappa_l \lambda_l}. \tag{16.6}$$

In the expression for the recruiting wedge, λ_l is the job separation rate, and $q_l(\theta_l) = m_l(1/\theta_l, 1)$ is the job filling rate, itself determined by the labor market matching function $m_l(U_l, V_l)$. In a slackish model, the production function does not tell us how much is sold (the output), but instead tells us how much could be sold (the capacity).

The labor demand in chapter 11 can therefore be used here, but with an additional term that captures slack on the product market. The labor demand gives us the number of workers that firms want to hire, with the goal of maximizing profits, for a given product market tightness, labor market tightness, and real wage. In chapter 11, because we only focus on the labor market, all the goods produced by firms are assumed to be sold. Here, by contrast, only a share $1 - u_p(\theta_p)$ of the firm's production capacity $k(n)$ is sold—because there is slack on the product market—so the labor demand becomes

$$l^d(\theta_p, \theta_l, w) = \left[\frac{(1-\alpha_l)\left[1-u_p(\theta_p)\right]a_l}{w}\right]^{1/\alpha_l} \cdot \frac{1}{\left[1+\tau_l(\theta_l)\right]^{1/\alpha_l - 1}}. \tag{16.7}$$

The main difference with the labor demand in chapter 11 is that now the labor demand curve depends on the slack rate in the product market and thus the product market tightness. So the labor demand is much more realistic than in the labor market model: instead of just depending on labor productivity, it also now depends on the demand for the firm's product. So both changes in technology and changes in demand affect labor demand. However, while the labor demand shifters might be different, the shape of the labor demand curve—how it depends on labor market tightness—remains the same.

16.2.3. Equilibrium aggregate supply

The equilibrium aggregate supply is almost the same as in chapter 14, but it must be extended to capture the fact that aggregate capacity is not exogenous but is determined by firms' production function and employment decisions. The aggregate supply is an equilibrium object as it assumes that flows are balanced on the product market.

Because the representative firm only sells a share $1 - u_p(\theta_p)$ of its productive capacity $k(n)$, the equilibrium aggregate supply is

$$y^s(\theta_p, n) = \left[1 - u_p(\theta_p)\right] k(n), \tag{16.8}$$

where $u_p(\theta_p)$ is the equilibrium slack rate on the product market, given by (16.3), and $k(n)$ is aggregate capacity, given by (16.4).

The aggregate supply gives the output on the product market. Output is always less than the aggregate capacity because the product market is slackish, so the slack rate $u_p(\theta_p) > 0$.

In (16.8) we see that the product market and labor market interact through the aggregate supply curve as well. In the same way that the labor demand curve (16.7) depends both on product market tightness and labor market tightness, the aggregate supply curve depends on product market tightness and employment, which itself depends on labor market tightness. Thus, we see that the aggregate supply also acts as a bridge between the labor market and product market.

In fact, we know that the number of producers in the labor market is

$$n = \frac{1 - u_l(\theta_l)}{1 + \tau_l(\theta_l)} \cdot h,$$

as the producers are people who are in the labor force but are neither unemployed nor recruiters. With this result, we rewrite the aggregate supply curve as a function of the two tightnesses:

$$y^s(\theta_p, \theta_l) = \left[1 - u_p(\theta_p)\right] k\left(\frac{1 - u_l(\theta_l)}{1 + \tau_l(\theta_l)} \cdot h\right). \tag{16.9}$$

16.2.4. Equilibrium aggregate demand

The households in our two-market model behave very similarly to the households in the basic model of chapter 14, so there is no need to spend time on solving the household problem—everything is essentially the same as in chapter 14.

The household's real budget constraint is slightly modified, because households now receive a wage from firms instead of receiving income from self-employment. The real budget constraint is now:

$$\dot{b}(t) = rb(t) + w\left[1 - u_l(\theta_l(t))\right] h - \left[1 + \tau_p(\theta_p(t))\right] c(t) + \mathcal{P}(t) - \frac{T(t)}{p(t)}. \tag{16.10}$$

There are two differences from the real budget constraint in chapter 14. The first is that the income of the household comes from the wages received from firms. The real wage is w, and the number of workers in firms is just the share $1 - u_l$ of the labor force h that is employed. The second is that households receive the profits $\mathcal{P}$ from firms, which are rebated to them. The households receive the profits because they naturally own the firms, since there is no one else in the economy who could own them.

However, the modifications to the budget constraint do not affect the household's problem. The household chooses consumption $c(t)$ and real bonds $b(t)$ to maximize utility, and as (16.10) shows, the terms with $c(t)$ and $b(t)$ are unaffected, so the solution to the household's problem is the same.

From the optimal amount of consumption, we compute the amount of output that households wish to purchase: $y = \left[1 + \tau_p(\theta_p)\right] c$. That amount of output constitutes the equilibrium aggregate demand, and it has exactly the same expression as in chapter 14:

$$y^d(\theta_p, r) = \frac{\left[(1 - \alpha_p)(\delta - r)a_p\right]^{1/\alpha_p}}{\left[1 + \tau_p(\theta_p)\right]^{1/\alpha_p - 1}}, \tag{16.11}$$

where a_p and α_p are parameters from the household's utility function, which takes the same form as in chapter 14:

$$\int_0^\infty \exp(-\delta t)\left[c_j(t)^{1-\alpha_p} + \frac{1}{a_p} \cdot \left[b_j(t) - b(t)\right]\right] dt, \tag{16.12}$$

where j is the index of the individual household.

16.3. Solution of the model

We are now ready to solve the model. We first prove the existence and uniqueness of the solution analytically, and we then represent the solution graphically—which is useful to understand the mechanics of the model.

16.3.1. Existence and uniqueness of the solution

The structure of the solution to this chapter's business cycle model is similar to the structure of the solution of the business cycle model of chapter 14, except that the number of variables is about double, since this model features not one but two slackish markets. In particular, the key step now is to determine both the product market tightness and the labor market tightness. From the values of tightnesses, we then infer the values of all the other variables in the model.

Since we have two markets that interact with each other, solving the two-market model requires a little more work. We need to find the product market tightness θ_p and labor market tightness θ_l such that the aggregate demand equals aggregate supply on the product market, and labor demand equals labor supply on the labor market:

$$y^d(\theta_p, r) = y^s(\theta_p, \theta_l) \tag{16.13}$$

$$l^d(\theta_p, \theta_l, w) = l^s(\theta_l), \tag{16.14}$$

where the supply and demand curves are introduced above.

We first need to transform our two-equation system into a one-equation system to establish that the model always admits a solution and the solution is unique. That one equation will also be helpful to study the properties of the solution in the rest of the chapter.

Let us first consider the product market equation, given by (16.13). Separating the terms in θ_p and θ_l, and using the production function (16.4), it gives:

$$\frac{\left[(1-\alpha_p)(\delta - r)a_p\right]^{1/\alpha_p}}{a_l h^{1-\alpha_l}} \left[\frac{1+\tau_l(\theta_l)}{1-u_l(\theta_l)}\right]^{1-\alpha_l} = \left[1-u_p(\theta_p)\right]\left[1+\tau_p(\theta_p)\right]^{1/\alpha_p - 1}. \tag{16.15}$$

Now, let us look at the labor market equation, given by (16.14). Separating the terms in θ_p and θ_l, and raising both sides to the power of α_l, it gives:

$$\frac{wh^{\alpha_l}}{(1-\alpha_l)a_l}\left[1-u_l(\theta_l)\right]^{\alpha_l}\left[1+\tau_l(\theta_l)\right]^{1-\alpha_l} = 1 - u_p(\theta_p). \tag{16.16}$$

The main challenge here is that the term $[1+\tau_l(\theta_l)]/[1-u_l(\theta_l)]$ is not monotonic in θ_l in equation (16.15). So we need to eliminate that term to make progress. We do that by dividing (16.15) by (16.16):

$$\left[1+\tau_p(\theta_p)\right]^{1-1/\alpha_p} = \frac{wh}{(1-\alpha_l)\left[(1-\alpha_p)(\delta-r)a_p\right]^{1/\alpha_p}} \cdot \left[1-u_l(\theta_l)\right]. \tag{16.17}$$

We now rewrite both equations in a similar form: as formulas giving product market tightness as a function of labor market tightness. Equation (16.16) then says that product market tightness is a function of labor market tightness: $\theta_p = \theta_p^l(\theta_l)$, where

$$\theta_p^l(\theta_l, w) = u_p^{-1}\left(1 - \frac{wh^{\alpha_l}}{(1-\alpha_l)a_l}\left[1-u_l(\theta_l)\right]^{\alpha_l}\left[1+\tau_l(\theta_l)\right]^{1-\alpha_l}\right). \tag{16.18}$$

Here u_p^{-1} is the inverse of $\theta_p \mapsto u_p(\theta_p)$, which is well defined since u_p is strictly decreasing on $[0, \bar{\theta}_p] \to [u_p(\bar{\theta}_p), 1]$ and hence invertible. We infer the properties of the function θ_p^l from the properties of the functions u_p^{-1}, u_l, and τ_l. We see that θ_p^l is strictly increasing in θ_l, and that $\theta_p^l(0) = 0$. There is also a $\theta_l^l < \bar{\theta}_l$ such that $\theta_p^l(\theta_l^l) = \bar{\theta}_p$.

To get our second relationship, we look at equation (16.17). It says that product market tightness is another function of labor market tightness: $\theta_p = \theta_p^p(\theta_l)$, where

$$\theta_p^p(\theta_l, r, w) = \tau_p^{-1}\left(\frac{(1-\alpha_l)\left[(1-\alpha_p)(\delta-r)a_p\right]^{1/(1-\alpha_p)}}{(wh)^{\alpha_p/(1-\alpha_p)}} \cdot \frac{1}{\left[1-u_l(\theta_l)\right]^{\alpha_p/(1-\alpha_p)}} - 1\right). \tag{16.19}$$

Here τ_p^{-1} is the inverse of $\theta_p \mapsto \tau_p(\theta_p)$, which is well defined since τ_p is strictly increasing on $[0, \bar{\theta}_p) \to [\tau_p(0), \infty)$ and hence invertible. We see that the function θ_p^p is strictly decreasing in θ_l. We also see that $\theta_p^p(0) = \bar{\theta}_p$. Finally, we see that there is a labor market tightness θ_l^p such that the function θ_p^p is well defined on $[0, \theta_l^p]$. If

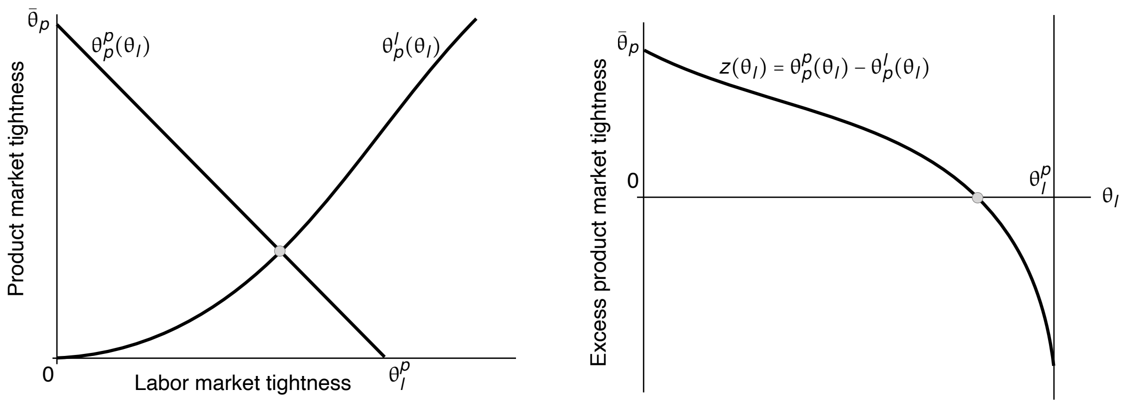
$$\frac{(1-\alpha_l)\left[(1-\alpha_p)(\delta-r)a_p\right]^{1/(1-\alpha_p)}}{(wh)^{\alpha_p/(1-\alpha_p)}} \cdot \frac{1}{\left[1-u_l(\theta_l^l)\right]^{\alpha_p/(1-\alpha_p)}} \geq 1 + \tau_p(0),$$

then θ_p^p is well defined on $[0, \theta_l^l]$ and $\theta_p^p(\theta_l^l) \geq 0$, so we set $\theta_l^p = \theta_l^l$. If the inequality above does not hold, then there exists $\theta_l^p < \theta_l^l$ such that

$$\frac{(1-\alpha_l)\left[(1-\alpha_p)(\delta-r)a_p\right]^{1/(1-\alpha_p)}}{(wh)^{\alpha_p/(1-\alpha_p)}} \cdot \frac{1}{\left[1-u_l(\theta_l^p)\right]^{\alpha_p/(1-\alpha_p)}} = 1 + \tau_p(0),$$

and then θ_p^p is well defined on $[0, \theta_l^p]$ and $\theta_p^p(\theta_l^p) = 0$.

We are now able to see that our two-market model has a unique solution. Indeed, solving the model is equivalent to finding the labor market tightness θ_l that solves the



A. Product market tightness curves

B. Existence and uniqueness of the solution

FIGURE 16.1. One-diagram representation of the model solution

The $\theta^l_p(\theta_l)$ curve is given by equation (16.18). The $\theta^p_p(\theta_l)$ curve is given by equation (16.19).

equation

$$\theta^l_p(\theta_l, w) = \theta^p_p(\theta_l, r, w). \tag{16.20}$$

We establish the existence and uniqueness of the solution by introducing the excess tightness function:

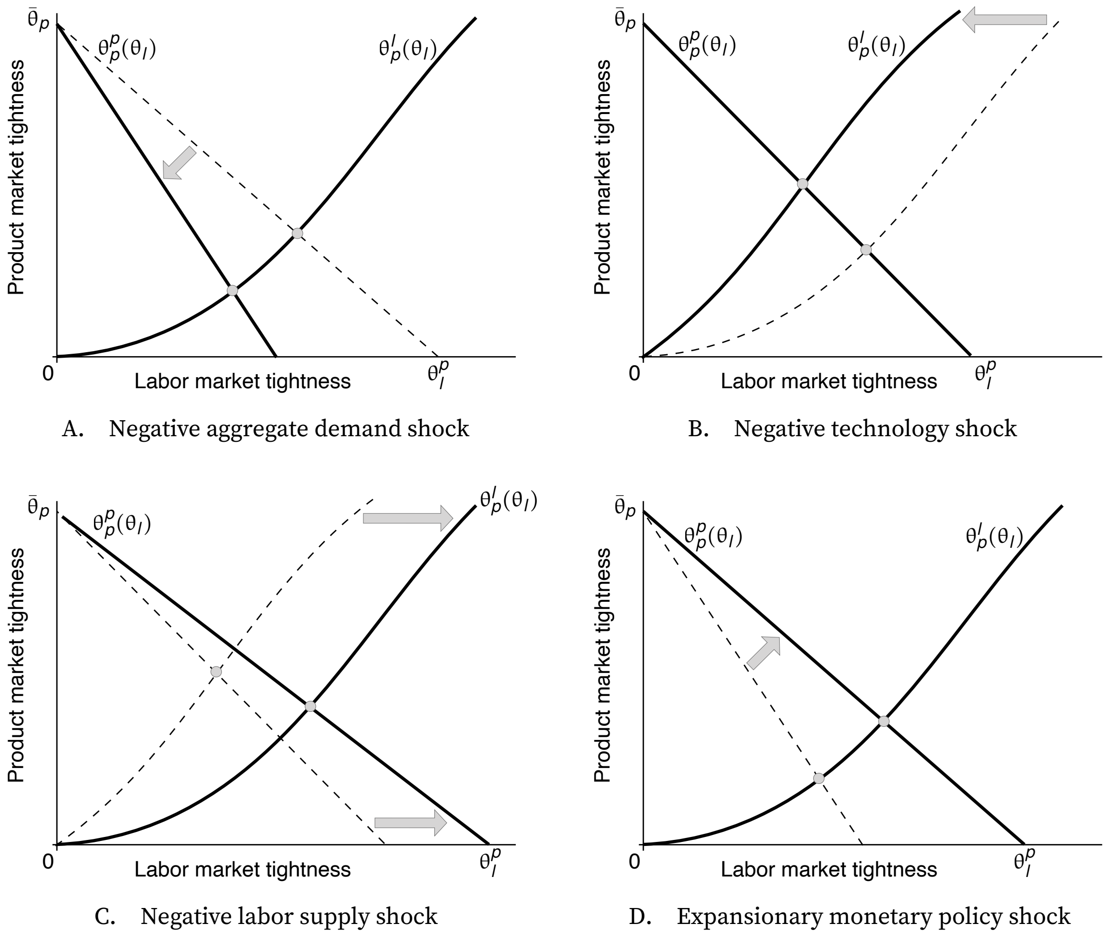
$$z(\theta_l, r, w) = \theta^p_p(\theta_l, r, w) - \theta^l_p(\theta_l, w). \tag{16.21}$$

With the excess tightness function, the solution of the model simply is

$$z(\theta_l, r, w) = 0.$$

We know that $\theta^p_p(\theta_l, r, w)$ is strictly decreasing in θ_l on $[0, \theta^p_l]$, starting from $\theta^p_p(0, r, w) = \bar{\theta}_p$ when $\theta_l = 0$, and reaching $\theta^p_p(\theta^p_l, r, w) = 0$ when $\theta_l = \theta^p_l$ if $\theta^p_l < \theta^l_l$ or $\theta^p_p(\theta^p_l, r, w) \geq 0$ when $\theta_l = \theta^p_l$ if $\theta^p_l = \theta^l_l$. At the same time, $\theta^l_p(\theta_l, w)$ is strictly increasing in θ_l on $[0, \theta^l_l]$, starting from $\theta^l_p(0, w) = 0$ when $\theta_l = 0$ and reaching $\theta^l_p(\theta^l_l, w) = \bar{\theta}_p$ when $\theta_l = \theta^l_l$. Moreover, both θ^p_p and θ^l_p are continuous in θ_l. The two curves are illustrated in figure 16.1A.

Thus, we know that the excess tightness function z is continuous in θ_l, and it declines from $z(0, r, w) = \bar{\theta}_p > 0$ to $z(\theta^p_l, r, w) < 0$ when θ_l increases from 0 to θ^p_l. Thus, by Bolzano's theorem, the equation $z(\theta_l, r, w) = 0$ has a solution on $(0, \theta^p_l)$ (result A.1). Moreover, since the excess tightness function is strictly decreasing, the solution is unique (figure 16.1B).



A. Negative aggregate demand shock

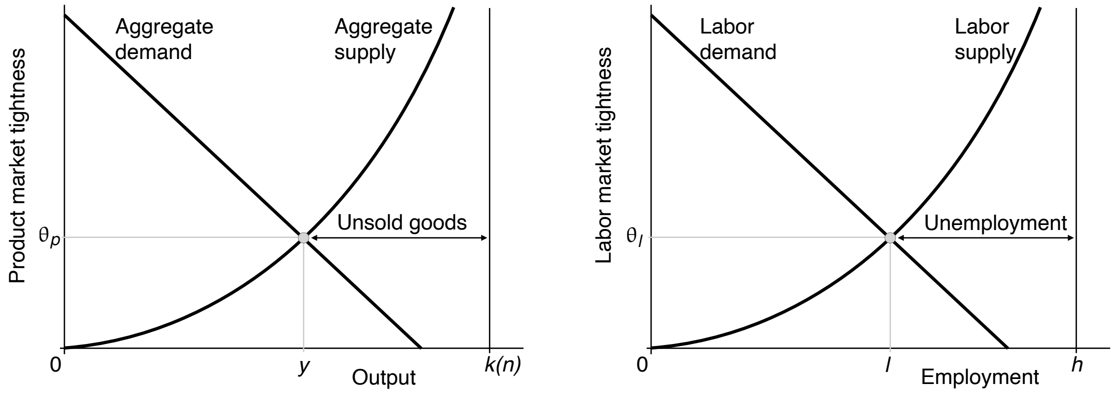
B. Negative technology shock

C. Negative labor supply shock

D. Expansionary monetary policy shock

FIGURE 16.2. Aggregate shocks in the one-diagram solution representation

The $\theta_p^l(\theta_l)$ curve is given by equation (16.18). The $\theta_p^p(\theta_l)$ curve is given by equation (16.19).



A. Product market B. Labor market

FIGURE 16.3. Two-diagram representation of the model solution

The aggregate supply curve is given by equation (16.8). The aggregate demand curve is given by equation (16.11). The labor supply curve is given by equation (16.1). The labor demand curve is given by equation (16.7).

16.3.2. Graphical representation of the solution

We have seen that the two-market model reduces to a system of two supply-equals-demand equations: (16.13) and (16.14). To visualize how the model operates and how labor market and product market interact with each other, we represent the solution of the model graphically in two diagrams: one diagram plots labor demand and labor supply in an employment-labor market tightness plane, and the other diagram plots aggregate demand and aggregate supply in an output-product market tightness plane. This graphical representation of the solution is presented in figure 16.3.

Once we have the product market tightness, we deduce output by the aggregate demand curve since it does not depend on labor market tightness. Similarly, once we have the labor market tightness, we deduce employment by the labor supply curve since it does not depend on product market tightness. Then, both tightnesses must equate aggregate demand and aggregate supply as well as labor demand and labor supply. Thus, the interaction between the two markets occurs through the labor demand and aggregate supply curves.

16.4. Keynesian, classical, and frictional unemployment

In chapter 11, we showed that the slackish labor market model offers a unified theory of unemployment, including both job rationing and frictional unemployment. One limitation of that model, however, is that job rationing is entirely due to labor productivity that is insufficient compared to real wages. Because the labor market model does not feature a separate product market, it cannot capture the idea that not all job rationing is due to excessive wages—some of it is due to insufficient product demand.

This chapter's model connects the slackish labor market to a slackish product market, which provides us with a complete theory of unemployment. In the model, unemployment can be decomposed into three components: Keynesian and classical components, in the sense of Malinvaud (1977, figure 3), and a frictional component, as in the DMP model. Unemployment has a Keynesian component because it depends on how easy or difficult it is for firms to sell their products; it has a classical component because it depends on how high or low the real wage is; and it has a frictional component because it depends on how easy or difficult it is for firms to recruit workers.

Formally, the labor demand curve is given by (16.7). We can see the different elements that drive unemployment. The real wage, w, captures the classical component of unemployment. When it is high, the labor demand decreases and unemployment goes up as a result. We also clearly see the Keynesian component of unemployment, which shows up in the $u_p(\theta_p)$ term, which is determined by aggregate demand. When the aggregate demand is small, product market slack increases, which reduces labor demand. This in turn increases unemployment. Lastly, we also see frictional unemployment in the $\tau_l(\theta_l)$ term, which is determined by recruiting costs. When recruiting costs increase, the recruiting wedge increases which means labor demand is lower. As a result, there is an increase in unemployment.

16.5. Disentangling labor demand shocks

In chapter 11, we argued that labor demand shocks are the main source of unemployment fluctuations in the United States. We reached this conclusion by observing that employment level and labor market tightness are positively correlated. This chapter's model allows us to go one step further: it allows us to determine whether these labor demand shocks are caused by aggregate demand shocks or technology shocks.

16.5.1. Aggregate demand shocks

The most natural source of a negative aggregate demand shock is a decrease in the taste for consumption relative to saving, a_p. Another possible negative aggregate demand shock is a decrease in the time discount rate, δ. After such a shock, households become more thrifty: they desire to save more and consume less, which depresses aggregate demand (equation (16.11)).

Graphically, the shock triggers an inward rotation of the aggregate demand curve (figure 16.4A). This leads to a reduction in product market tightness θ_p and an increase in product market slack $u_p(\theta_p)$. The increased product market slack in turn depresses the labor demand curve, which rotates inward (figure 16.4B). This reduction in labor demand depresses the labor market tightness θ_l, and raises the unemployment rate $u_l(\theta_l)$.

Because labor market tightness drops, the number of producers $n(\theta_l)$ might change, so the aggregate capacity $k(n(\theta_l))$ might change, and there might be either a dampening or an accentuation of the initial shock on the product market. If the labor market is operating efficiently, $n(\theta_l)$ is maximized so does not respond to a small change in labor market tightness θ_l. If the labor market is inefficiently tight, $n(\theta_l)$ and $k(n(\theta_l))$ increase as θ_l drops. If the labor market is inefficiently slack, $n(\theta_l)$ and $k(n(\theta_l))$ decrease as θ_l drops.

The changes in aggregate capacity themselves lead to shifts in the aggregate supply curve. If the aggregate supply curve shifts inward, product market tightness moves back up; if the aggregate supply curve shifts outward, product market tightness moves further down. Of course, these changes in product market tightness further affect labor market tightness. The effect of the aggregate demand shock and linkage across markets is illustrated in figure 16.4C in the case of an inefficiently slack labor market, such that aggregate capacity drops after labor market tightness drops. That increase in product market tightness feeds itself back to the labor market, which pushes the labor demand slightly back up (figure 16.4D).

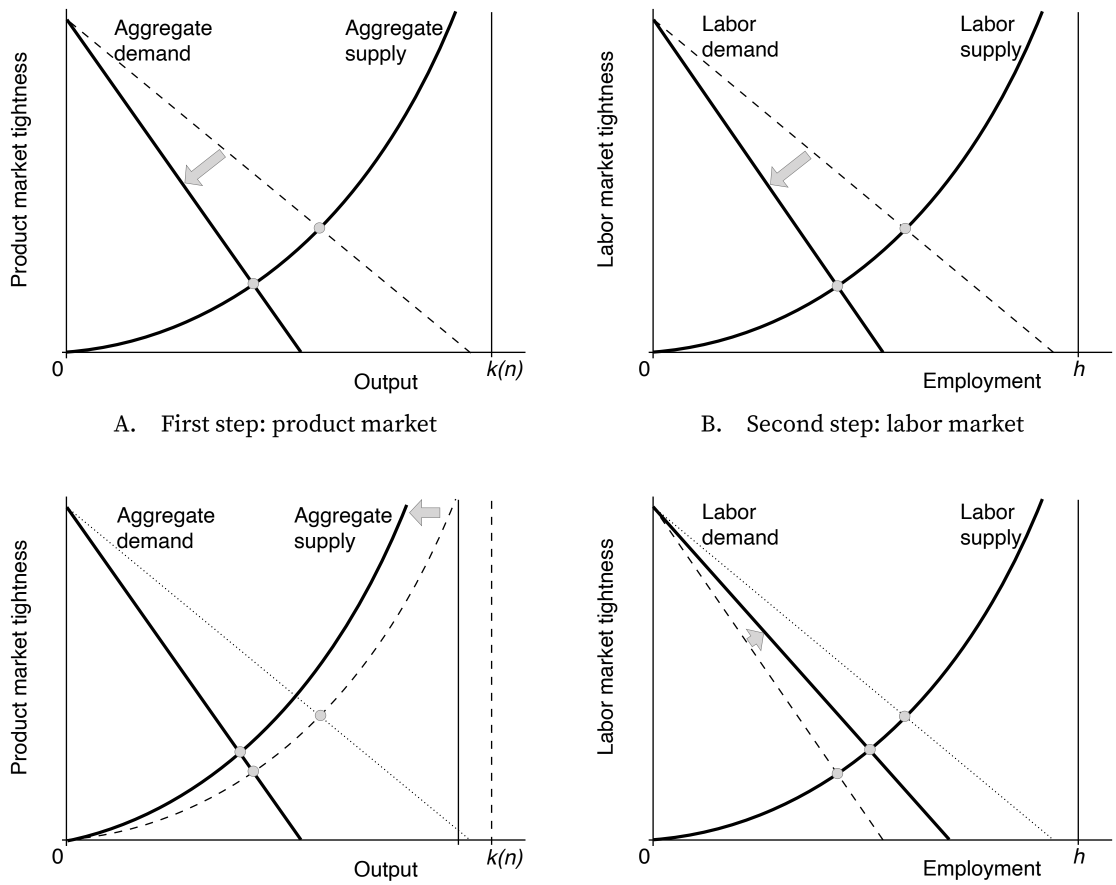
Given the feedback from the labor market to the product market, it is not entirely clear from equations (16.13) and (16.14) what eventually happens to product and labor market tightnesses. But using the functions $\theta_p^p(\theta_l)$ and $\theta_p^l(\theta_l)$, we can establish how the tightnesses respond.

After a negative aggregate demand shock, whether a decrease in the taste for consumption a_p or discount rate δ, we see that $\theta_p^p(\theta_l)$, given by (16.19), shifts down, while $\theta_p^l(\theta_l)$, given by (16.18), stays the same. Thus, given equation (16.20), we infer that both tightnesses, θ_p and θ_l, decrease (figure 16.2A). Thus, maybe as expected, the response of the tightnesses is determined by the first-round response to the negative shock.

From the tightness results we infer a few other results: the unemployment rate, $u_l(\theta_l)$, increases and the slack rate on the product market, $u_p(\theta_p)$, also increases: there is more slack on both markets. Because the unemployment rate increases, the employment level l decreases.

It is difficult, however, to determine how output changes just by looking at tightnesses. As the aggregate demand curve shifts inward, output tends to be lower. But as the product market tightness drops, the economy moves down along the aggregate demand curve, which raises output. To determine what happens overall, we need to use the labor-share result from chapter 11. In equation (11.9) we found using the firms' first-order condition that firms' wage bill is a share $1-\alpha_l$ of their sales. The logic carries over here, even if not all productive capacity is sold, so that

$$(1-\alpha_l)\,y = wl. \tag{16.22}$$



A. First step: product market

B. Second step: labor market

C. Third step: back to product market

D. Fourth step: back to labor market

FIGURE 16.4. Negative aggregate demand shock in the slackish business cycle model

The aggregate supply curve is given by equation (16.8). The aggregate demand curve is given by equation (16.11). The labor supply curve is given by equation (16.1). The labor demand curve is given by equation (16.7).

From this we clearly see what happens to output: since employment decreases but the real wage is unaffected, the wage bill drops, and therefore output y drops.

This completes our comparative statics for aggregate demand shocks, which are summarized in table 16.2.

16.5.2. Technology shocks

We now look at the model's response to technology shocks. A negative technology shock corresponds to a decrease in the technology parameter in the production function (16.4), a_l.

The negative technology shock simultaneously triggers an inward shift of the aggregate supply curve (figure 16.5A) and an inward rotation of the labor demand curve (figure 16.5B). These movements lead to an increase in product market tightness and a decrease in labor market tightness. This means in turn that the product market slack rate decreases while the unemployment rate increases.

These tightness changes feed back to the product and labor markets. The increased product market tightness, and reduced product market slack, boosts labor demand, so the labor demand curve rotates back outward (figure 16.5D). Just as with the aggregate demand shock, the initial drop in labor market tightness might affect the number of producers and aggregate capacity, and there might be either a dampening or an accentuation of the initial aggregate supply shock on the product market. Figure 16.5C illustrates what occurs on the product market if the labor market is inefficiently slack, such that aggregate capacity drops after labor market tightness drops. Then the aggregate supply curve shifts inward further, and product market tightness moves up further. Of course, the change in product market tightness further affects labor market tightness.

Once again, we use the functions $\theta_p^p(\theta_l)$ and $\theta_p^l(\theta_l)$ to establish how the tightnesses respond in the presence of linkage across markets. We see that when technology a_l decreases, the function $\theta_p^p(\theta_l)$, given by (16.19), is unaffected, while the function $\theta_p^l(\theta_l)$, given by (16.18), shifts up. Thus, given equation (16.20), we infer that labor market tightness, θ_l, decreases while product market tightness, θ_p, increases (figure 16.2B). Once again, maybe as expected, the response of the tightnesses is determined by the first-round response to the negative shock.

From the tightness results we infer a few other results: the unemployment rate, $u_l(\theta_l)$, increases but the slack rate on the product market, $u_p(\theta_p)$, decreases: there is more slack on the labor market but less on the product market. Because the unemployment rate increases, the employment level l decreases. As product market tightness increases, the economy is moving up along the fixed aggregate demand curve, so the output level y decreases too.

The comparative statics for technology shocks are summarized in table 16.2.

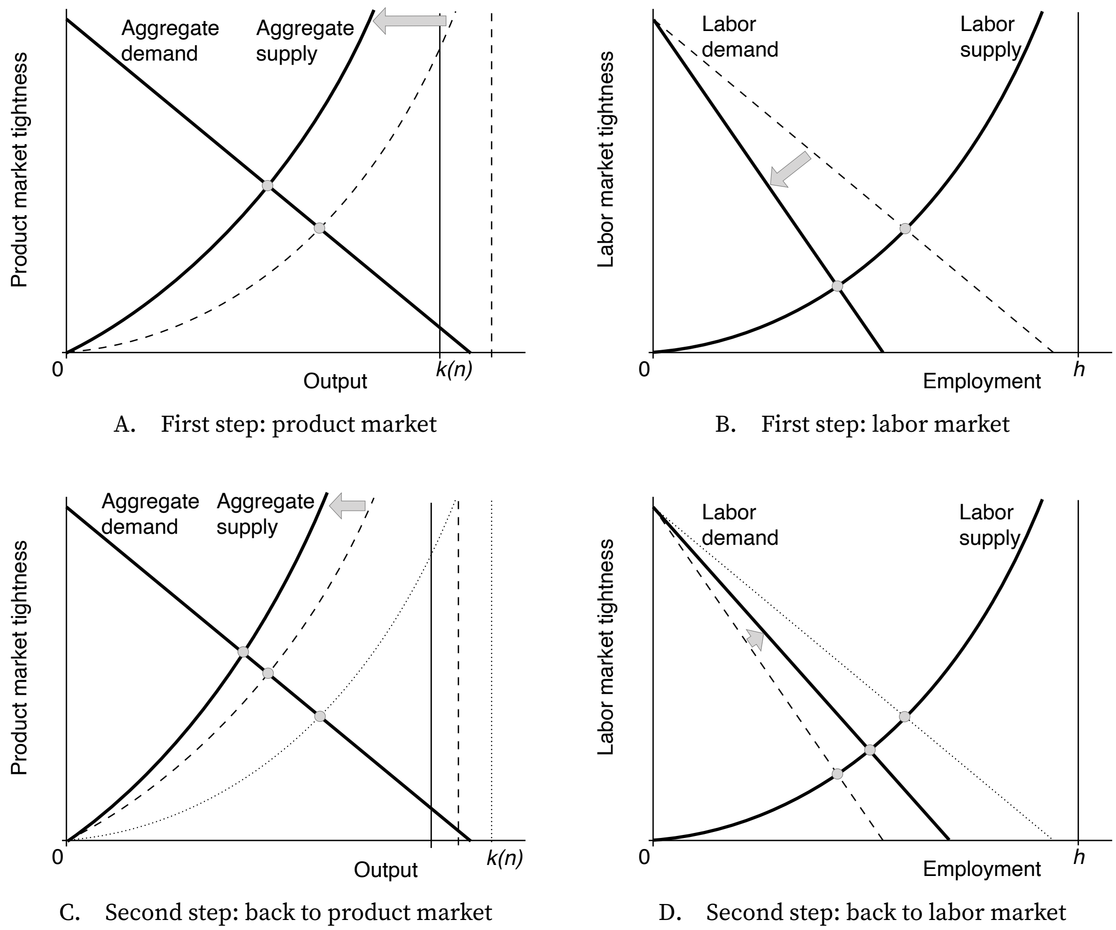


FIGURE 16.5. Negative technology shock in the slackish business cycle model

The aggregate supply curve is given by equation (16.8). The aggregate demand curve is given by equation (16.11). The labor supply curve is given by equation (16.1). The labor demand curve is given by equation (16.7).

16.5.3. Labor supply shocks

For completeness, and to contrast labor demand shocks, we finally consider the effects of labor supply shocks in the model. The most natural source of a negative labor supply shock is a decrease in the size of the labor force, h.

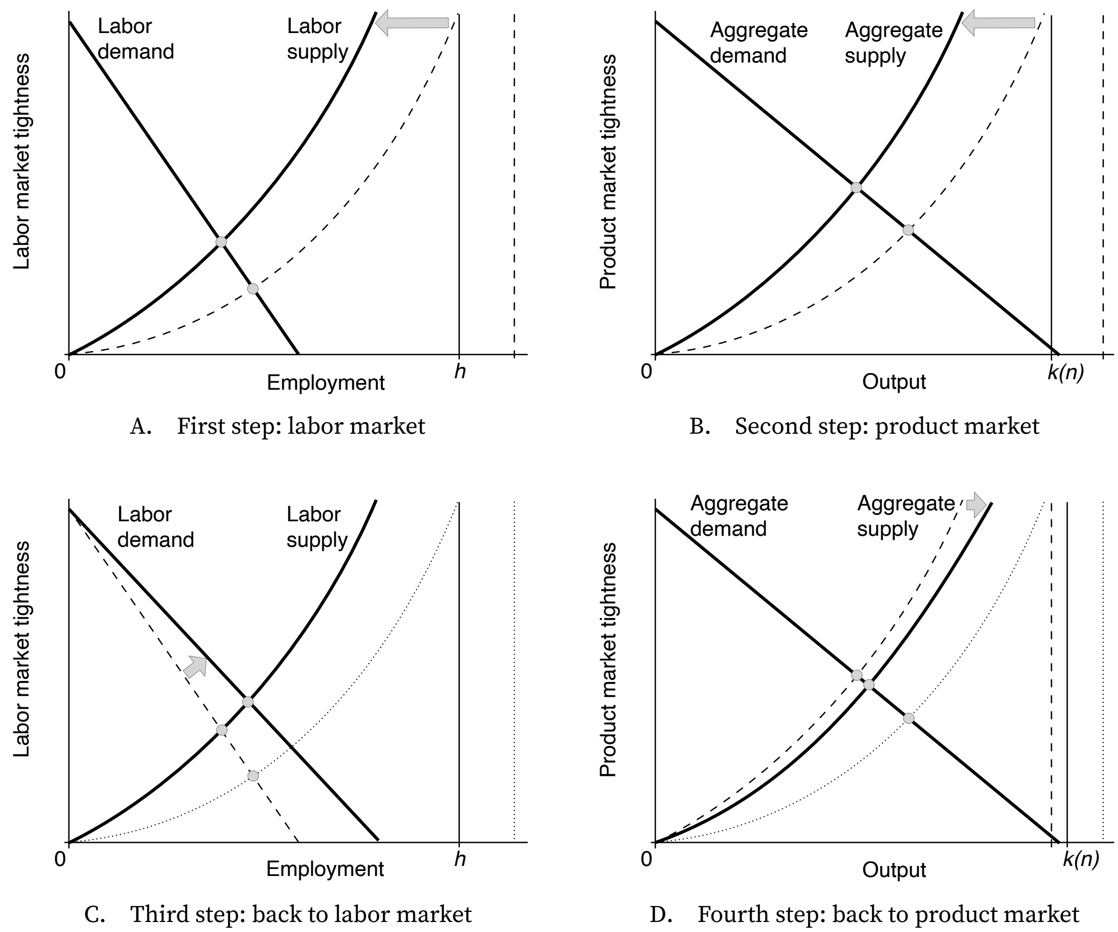
The negative labor supply shock triggers an inward shift of the labor supply curve (figure 16.6A). The shift leads to an increase in labor market tightness. This means in turn that the unemployment rate decreases and the recruiting wedge increases.

The labor market change feeds back to the product market. The labor market moves up along the labor demand curve, so employment decreases. Since the recruiting wedge increases due to the tighter labor market, the number of producers clearly drops. Aggregate capacity therefore declines, which means that the aggregate supply curve shifts inward (figure 16.6B). As the aggregate supply curve shifts inward, product market tightness increases. Of course, the change in product market tightness further affects labor market tightness: a higher product market tightness means a lower product market slack rate, which stimulates the labor demand curve, and pushes labor market tightness further up (figure 16.6C). That change in labor market tightness might further change the number of producers and aggregate supply—for instance boost the aggregate supply curve if the labor market is inefficiently slack (figure 16.6D).

Once again, we use the functions $\theta_p^p(\theta_l)$ and $\theta_p^l(\theta_l)$ to establish how the tightnesses respond, once the cross-market linkages are accounted for. We see that when the labor force h decreases, the function $\theta_p^p(\theta_l)$, given by (16.19), shifts up, while the function $\theta_p^l(\theta_l)$, given by (16.18), shifts down. Thus, we infer that labor market tightness, θ_l, unambiguously increases (figure 16.2C).

What happens to product market tightness, θ_p, is not entirely clear from the shifts in the two functions $\theta_p^p(\theta_l)$ and $\theta_p^l(\theta_l)$ (figure 16.2C again). But we can use a proof by contradiction to show that θ_p eventually increases. Let us assume that θ_p decreases. As the product market moves down the aggregate demand curve, output y increases. Now, let us look at the labor demand equation, (16.7). Under our assumption that θ_p decreases, the product market slack rate $u_p(\theta_p)$ increases, which depresses the labor demand. In addition, the labor market moves up the labor demand curve as labor market tightness increases. Both changes imply that employment decreases. But here we reach a contradiction, because output and employment must move in the same direction. Indeed, the labor share is simply $1 - \alpha_l$, as shown by (16.22). An increase in output means that employment increases too, since real wages are fixed. From this contradiction we learn that the product market tightness must increase. Once again, we find that the response of the tightnesses is determined by the first-round response to the shock.

From the tightness results we infer a few other results: the unemployment rate, $u_l(\theta_l)$, decreases and the slack rate on the product market, $u_p(\theta_p)$, also decreases: there is less



A. First step: labor market

B. Second step: product market

C. Third step: back to labor market

D. Fourth step: back to product market

FIGURE 16.6. Negative labor supply shock in the slackish business cycle model

The aggregate supply curve is given by equation (16.8). The aggregate demand curve is given by equation (16.11). The labor supply curve is given by equation (16.1). The labor demand curve is given by equation (16.7).

slack on both markets after the negative labor supply shock. As the product market moves up the aggregate demand curve, output decreases. Using the labor share logic, we infer that employment decreases with output.

The comparative statics for labor supply shocks are summarized in table 16.2 as well.

16.5.4. Source of unemployment fluctuations

The comovements of quantities and prices, or in a macroeconomic model, of output and inflation, are commonly used to identify the sources of market or business cycle fluctuations. In a slackish model, prices and inflation are determined by norms, so the approach is not available. Instead, as we already saw in chapter 11, the sources of fluctuations in slackish models can be identified from the comovements of quantities and tightnesses. In our business cycle model, in particular, Okun plots allow us to separate labor demand versus labor supply and technology versus aggregate demand shocks.

In chapter 11 we used labor market data to argue that unemployment fluctuations are driven by labor demand shocks. Here we can use standard Okun plots of changes in output against changes in unemployment rate to reach the same conclusion. Labor demand shocks can either be driven by technology or aggregate demand, as both enter the labor demand. But thankfully, both aggregate demand and technology shocks generate negative comovements between output and unemployment rate, so a downward-sloping Okun plot (table 16.2). By contrast, labor supply shocks generate positive comovements between output and unemployment rate, so an upward-sloping Okun plot (table 16.2). We showed in figure 2.11 that the output-unemployment Okun plot is downward sloping, as Okun's law stipulates, and from this we confirm that labor demand shocks cause unemployment fluctuations.

But which sort of labor demand shocks are the cause of the fluctuations: technology or aggregate demand shocks? Aggregate demand shocks generate negative comovements between output and product market slack rate whereas technology shocks generate positive comovements between output and product market slack rate (table 16.2). Hence, to ascertain whether the labor demand shocks causing unemployment fluctuations are aggregate demand or technology shocks, we simply need to plot the Okun relationship between output and product market slack rate. Under technology shocks that Okun relationship is upward sloping; under aggregate demand shocks it is downward sloping. The standard Okun plot relates output fluctuations to fluctuations in the unemployment rate; the Okun relationships that we use here plot output fluctuations against fluctuations in product market slack instead of labor market slack.

As it turns out, in the United States, short-run fluctuations in output and in product market slack rate are negatively correlated. We established this fact with figures 2.12 and 2.13. Such negative comovements between output and product market slack indicate

TABLE 16.2. Comparative statics in the two-market slackish business cycle model

Shock	Product market tightness θ_p	Product market slack rate u_p	Output y	Labor market tightness θ_l	Unemployment rate u_l	Employment l
Decrease in aggregate demand a_p	–	+	–	–	+	–
Decrease in technology a_l	+	–	–	–	+	–
Decrease in labor supply h	+	–	–	+	–	–
Decrease in nominal interest rate i	+	–	+	+	–	+

The comparative statics are obtained from figures 16.2A, 16.2B, 16.2C, and 16.2D. A variable's increase is denoted by "+" and a decrease by "-".

that business cycle fluctuations are mostly caused by aggregate demand shocks, not technology shocks.

16.6. Revisiting the effect of monetary policy on unemployment

In chapter 14, we showed how monetary policy is able to stabilize unemployment in a one-market business cycle model: it does so by modulating the nominal interest rate, which steers aggregate demand and then stabilizes aggregate tightness and thus unemployment. But how does monetary policy operate in a more realistic, two-market business cycle model? The nominal interest rate affects the aggregate demand and then product market tightness, while unemployment is determined by the labor market tightness.

16.6.1. How does monetary policy operate?

We consider an expansionary monetary policy: the central bank lowers the nominal interest rate i, which reduces the real interest rate $r = i - \pi$, given that inflation is fixed in this model too (just as in chapter 14). Since the real interest rate is lower, the financial returns on wealth are lower, so households are keener to spend and consume instead of saving, which stimulates the aggregate demand (equation (16.11)).

Graphically, the policy triggers an outward rotation of the aggregate demand curve (figure 16.7A). This raises product market tightness θ_p and lowers product market slack $u_p(\theta_p)$.

The reduced product market slack means that firms sell a larger share of their goods and services, which stimulates labor demand: the labor demand curve rotates outward, which boosts labor market tightness θ_l, and lowers the unemployment rate $u_l(\theta_l)$ (figure 16.7B).

Because labor market tightness rises, the number of producers employed by firms $n(\theta_l)$ might change, so the aggregate capacity $k(n(\theta_l))$ might change, which might affect the aggregate supply curve on the product market, just as we discussed in the case of aggregate demand shocks. For instance, if the labor market is inefficiently slack—the usual situation in which expansionary monetary policy is enacted—then the number of producers increases, so the aggregate supply curve shifts outward (figure 16.7C). In turn, output increases further but product market tightness moves back down somewhat.

Of course, these changes in product market tightness further affect labor market tightness. That decrease in product market tightness feeds back to the labor market: it pushes the labor demand curve slightly back down (figure 16.7D).

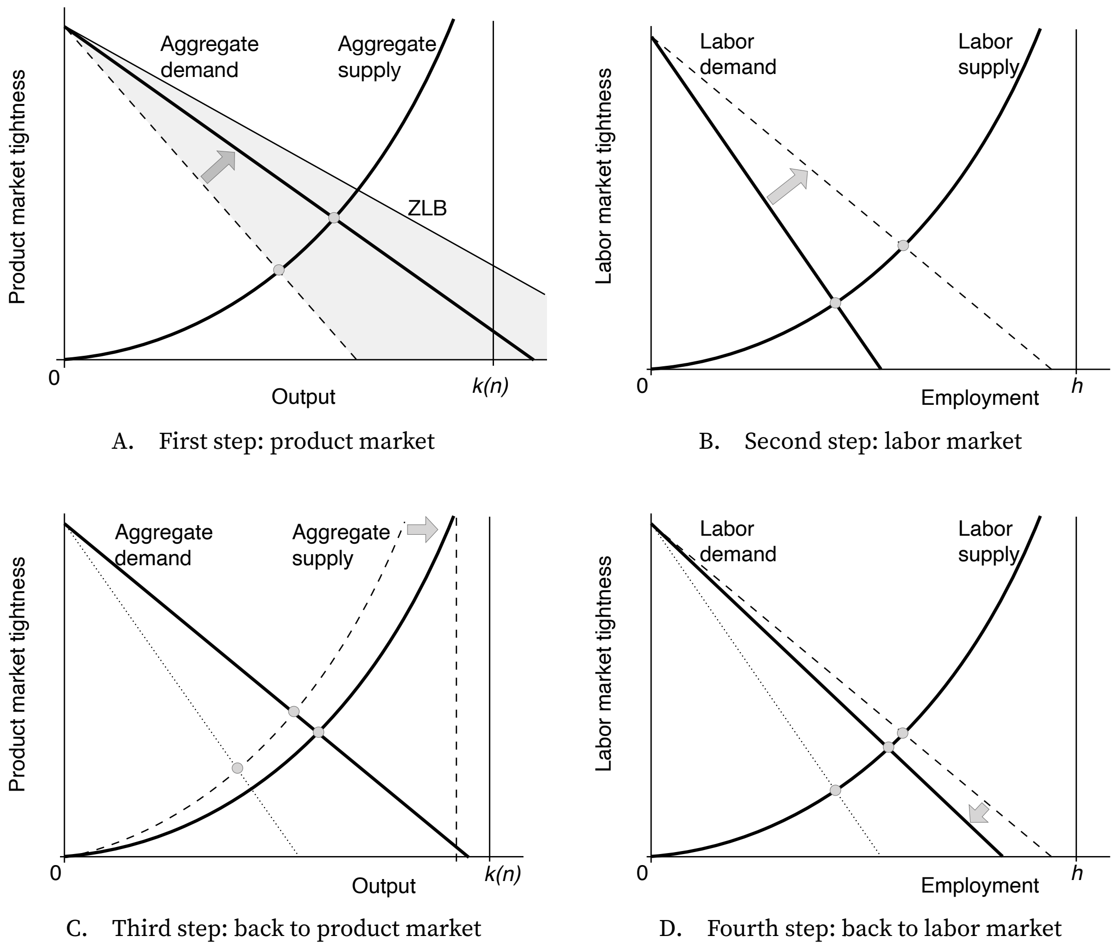


FIGURE 16.7. Expansionary monetary policy in the two-market slackish business cycle model

The aggregate supply curve is given by equation (16.8). The aggregate demand curve is given by equation (16.11). The labor supply curve is given by equation (16.1). The labor demand curve is given by equation (16.7). In panel A, the gray cone indicates all the positions that the aggregate demand curve can reach when the nominal interest rate is reduced from its current level to the zero lower bound. The aggregate demand curve at the zero lower bound is the most outward position that the aggregate demand curve can reach; it is obtained from equation (16.11) when $i = 0$ and $r = -\pi$.

16.6.2. Overall effects of monetary policy on the product and labor markets

Given the connection between labor market and product market, it is not entirely clear from equations (16.13) and (16.14) what eventually happens to product and labor market tightnesses. But using the functions $\theta_p^p(\theta_l)$ and $\theta_p^l(\theta_l)$, we can establish again how the tightnesses respond overall.

After a decrease in the real interest rate r, the curve $\theta_p^p(\theta_l)$, given by (16.19), shifts up, while the curve $\theta_p^l(\theta_l)$, given by (16.18), stays the same. Thus, overall, both product market tightness, θ_p, and labor market tightness, θ_l, increase after the expansionary monetary policy (figure 16.2D). Once again, the response of the tightnesses is determined by the first-round response to the shock.

From the tightness results we infer a few other results. Importantly, the unemployment rate, $u_l(\theta_l)$, falls after the decrease in the nominal interest rate. This is because the slack rate on the product market, $u_p(\theta_p)$, has fallen once aggregate demand has been stimulated, which has raised labor demand. Overall, there is less slack on both markets.

Because the labor market tightness increases, the employment level l increases, as the labor market moves up the labor supply curve. It is not easy to determine how output changes just by looking at tightnesses, because both aggregate supply and demand shift. But, using the labor-share result in equation (16.22), we conclude that output y rises because employment increases.

The comparative statics for a decrease in the nominal interest rate, which is an expansionary monetary policy shock, are summarized in table 16.2.

16.6.3. The monetary multiplier

In chapter 14 we computed the monetary multiplier du/di, which was given by equation (14.16). The transmission of monetary policy to unemployment is more complex in the two-market model, as the shift in aggregate demand caused by the change in interest rate has to travel first through product market tightness and then labor market tightness before reaching unemployment. Nevertheless, we can compute the monetary multiplier from equation (16.20). As appendix I shows, in this model the multiplier is given by:

$$\frac{du_l}{di} = \frac{1 - u_l(\theta_l)}{\delta - r} \cdot \frac{1}{\alpha_p + (1 - \alpha_p)\left[\alpha_l + (1 - \alpha_l)\frac{\eta_l(\theta_l)}{1-\eta_l(\theta_l)} \cdot \frac{\tau_l(\theta_l)}{u_l(\theta_l)}\right]\frac{\eta_p(\theta_p)}{1-\eta_p(\theta_p)} \cdot \frac{\tau_p(\theta_p)}{u_p(\theta_p)}}. \tag{16.23}$$

Many of the properties of the monetary multiplier remain the same in the two-market model as in the one-market model, with a few subtle differences.

First, the multiplier remains positive, reflecting our earlier finding that the unemployment rate rises when the nominal interest rate increases.

Second, when both product and labor markets are operating efficiently, we infer from

(10.11) that

$$\frac{\eta_l(\theta_l^*)}{1-\eta_l(\theta_l^*)}\cdot\frac{\tau_l(\theta_l^*)}{u_l(\theta_l^*)}=\frac{\eta_p(\theta_p^*)}{1-\eta_p(\theta_p^*)}\cdot\frac{\tau_p(\theta_p^*)}{u_p(\theta_p^*)}=1.$$

Hence, at efficiency, the monetary multiplier has the same value as in the one-market model:

$$\frac{du_l}{di}=\frac{1-u_l(\theta_l^*)}{\delta-r}.$$

So, at efficiency, the monetary multiplier solely depends on the efficient unemployment rate, discount rate, and real interest rate.

Third, the multiplier continues to be slack dependent, but it now depends both on labor market slack, governed by tightness θ_l, and product market slack, governed by tightness θ_p. In particular, the monetary multiplier is strictly decreasing in product market tightness, so monetary policy reduces unemployment more effectively when the product market is slack than when it is tight. The same is true for the labor market, at least if we omit the movements in $1-u_l(\theta_l)\approx 1$, as we did in the informal discussion of chapter 14. Then, the monetary multiplier is strictly decreasing in labor market tightness, so monetary policy reduces unemployment more effectively when the labor market is slack than when it is tight. Of course, if both labor and product markets are slack, the monetary multiplier is even higher, so monetary policy is a more potent tool to tackle unemployment.

The effect of monetary policy is symmetric so the same results hold if monetary policy wanted to raise unemployment by raising rates instead. Overall, monetary policy has a larger effect on unemployment in a slack economy than in a tight economy.

16.7. Revisiting other aggregate demand policies

In chapter 14, we discussed two policies besides conventional monetary policy that could be used to stabilize unemployment in a one-market business cycle model: fiscal policy in the form of public spending, and unconventional monetary policy in the form of forward guidance.

Both public spending and forward guidance operate by stimulating aggregate demand. Public spending does it mechanically: if the government buys goods and services on the product market, that immediately boosts aggregate demand, as equation (14.25) shows. Forward guidance boosts aggregate demand indirectly, by pushing down the costate variable on wealth in households' consumption-saving problems, which itself boosts aggregate demand, as equation (14.17) shows.

The two policies continue to stimulate aggregate demand in the exact same way in this chapter's two-market model. Their effects then percolate to the labor market just as in the case of conventional monetary policy, described in figure 16.7. Once the policy has stimulated aggregate demand, product market tightness increases, which reduces slack on the product market (figure 16.7A). Firms are able to sell more of their products, so it is profitable for them to hire more labor. This increase in labor demand boosts labor market tightness, which reduces unemployment as job seekers are able to find jobs more rapidly (figure 16.7B). The increase in employment feeds back into the product market, producing a secondary adjustment in product market tightness (figure 16.7C), which itself feeds back into the labor market to trigger a secondary adjustment in tightness there (figure 16.7D), and so on.

16.8. Summary

This chapter develops a slackish business cycle model with distinct labor and product markets. In the model, there are different types of unemployment: Keynesian unemployment, which is caused by a lack of aggregate demand; classical unemployment, which is caused by excessively high real wages; and frictional unemployment, which is caused by the cost of matching workers with firms. Most models do not capture these different types of unemployment—usually, a model focuses on one type of unemployment so different models are used to think about different types of unemployment. This is an issue because it does not provide a comprehensive view of what drives unemployment and unemployment fluctuations. One advantage of our slackish two-market model is that it is able to capture all these components, offering a completely unified theory of unemployment.

Previously we saw using employment-unemployment Okun plots that labor demand shocks and not labor supply shocks cause fluctuations in US unemployment. In this chapter we show using output-product market slack Okun plots that these labor demand shocks stem from aggregate demand shocks, not the technology shocks that are so often used in business cycle research.

Finally, the chapter shows how aggregate demand policies are able to stabilize unemployment. In the case of conventional monetary policy, for instance, a reduction in the interest rate stimulates aggregate demand, which raises product market tightness and thus reduces slack on the product market. Firms find it easier to sell their goods and services, so they want to hire more labor, post more vacancies, which boosts labor market tightness and reduces unemployment. Fiscal policy and unconventional monetary policy work in a similar fashion by stimulating the aggregate demand curve through either public spending or forward guidance promises.

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