Slides for Chapter 13: Nominal Rigidity, Exchange Rate Policy, and Unemployment

Columbia University

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These are the slides for the textbook, "International Macroeconomics: A Modern Approach," by Stephanie Schmitt-Grohé, Martín Uribe, and Michael Woodford, Princeton University Press, 2022, ISBN: 9780691170640.

Why is Exchange Rate Policy Important?

The traded-nontraded (TNT) model of Chapter 10 explains how the *real* exchange rate and the real wage are determined to ensure that the markets for goods and labor clear.

For example, a deterioration of the terms of trade reduces aggregate demand and causes a fall in the relative price of nontradable goods (the real exchange rate depreciates).

In the labor market, due to the fall in aggregate demand for goods, firms demand less labor, so the real wage falls to ensure that full employment is maintained.

Here, the *nominal* exchange rate plays no role. Why? Because all prices (good prices, wages, etc.) are flexible.

This chapter extends the TNT model to allow for nominal rigidity. In this new environment, there are no guarantees that markets will always clear, so what the central bank does with the nominal exchange rate becomes important.

What Happens under Nominal Rigidity?

Consider again the example of a deterioration in the terms of trade. The contraction in aggregate demand triggers a decline in the demand for labor by firms.

Equilibrium in the labor market requires a fall in the real wage.

A fall in the real wage can happen either through a fall in the nominal wage or through an increase in the consumer price level.

If the nominal wage is downwardly rigid, then the price level must rise for the labor market to clear. Otherwise, the real wage would be too high and involuntary unemployment would emerge.

In turn, an increase in the price level could be brought about by expansionary monetary policy and a depreciation of the domestic currency.

So, in the presence of nominal rigidity exchange rate policy plays a key role in preventing disruptions in the labor market.

The TNT-DNWR model

This chapter builds on the two-period TNT model of Chapter 10.

Relative to the TNT model, the model economy we study here features *downward nominal wage rigidity* (DNWR).

We will refer to the TNT model with downward nominal wage rigidity as the TNT-DNWR model.

This chapter is self contained—you don't need to read Chapter 10—and starts by presenting the model's main building blocks.

What's the difference between the nominal and the real wage?

The nominal wage is the usual notion of wage, that is, the wage expressed in units of currency. For example, if Chiara makes 45 euros per hour, then her nominal wage is 45 euros per hour.

The real wage is the wage expressed in units of some good (or basket of goods); that is, it is the nominal wage divided by the price of some good (or basket of goods). For example, if the price of 1 apple is 2 euros, then Chiara's real wage is 22.5 apples.

Typically, the real wage is expressed in terms of a broad basket of goods. For example, if one divides the nominal wage by the consumer price level, the real wage is expressed in units of the typical basket of goods and services consumed by households.

Downward Nominal Wage Rigidity

In low inflation countries, whether developed or emerging, each year only a small fraction of workers experience a wage cut. Almost half of all workers experience an exact zero change in their wages, and almost half experience a wage increase.

Furthermore, during recessions the fraction of workers with zero wage change increases.

This pattern of wage changes has been interpreted as evidence of downward nominal wage rigidity.

Why are nominal wages downwardly rigid? This is still a matter of investigation.

When asked why wages don't fall during a recession, the most common answer among firm managers is that they don't cut wages because wage cuts undermine the morale of workers, which disrupts productivity in the workplace.

Modeling Downward Nominal Wage Rigidity

Let W_t denote the nominal hourly wage rate in period t.

Suppose that the nominal wage is subject to the following constraint:

$$W_t \geq W_{t-1}. \tag{1}$$

According to this restriction, the nominal wage rate can increase but it cannot fall.

The Law of One Price

Households consume tradable and nontradable goods. The country is small and open to international trade. The domestic price of the tradable good obeys the law of one price

$$P_t^T = \mathcal{E}_t P_t^{T*}.$$

where
P_t^T = domestic price of the tradable good
P_t^{T*} = foreign price of the tradable good.
$\mathcal{E}_t$ = nominal exchange rate defined as the domestic currency price of one unit of foreign currency—so an increase in $\mathcal{E}_t$ is a depreciation of the domestic currency.

For simplicity, assume that P_t^{T*} is constant and equal to 1. So we can use interchangeably the terms price of the tradable good and nominal exchange rate.

Endowments and Production

Assume that output of tradable goods, denoted Q_t^T, is an exogenous endowment.

Output of nontraded goods, denoted Q_t^N, is produced by perfectly competitive firms using labor, h_t, with the production function

$$Q_t^N = F(h_t),$$

where $F(\cdot)$ is assumed to be increasing and concave.

Firms in the nontraded sector sell goods at the price P_t^N and pay the wage rate W_t per unit of labor employed.

The Firm's Profit Maximization Problem

Profits of firms in the nontraded sector, denoted Π_t, are given by

$$\Pi_t = P_t^N F(h_t) - W_t h_t. \tag{2}$$

Firms choose employment, h_t, to maximize profits, taking as given P_t^N and W_t. The optimality condition is

$$P_t^N F'(h_t) = W_t. \tag{3}$$

Dividing both sides by $P_t^T (= \mathcal{E}_t)$,

$$\frac{P_t^N}{P_t^T} = \frac{W_t/\mathcal{E}_t}{F'(h_t)} \tag{4}$$

The optimality condition says that firms produce until the relative price equals the marginal cost.

Let

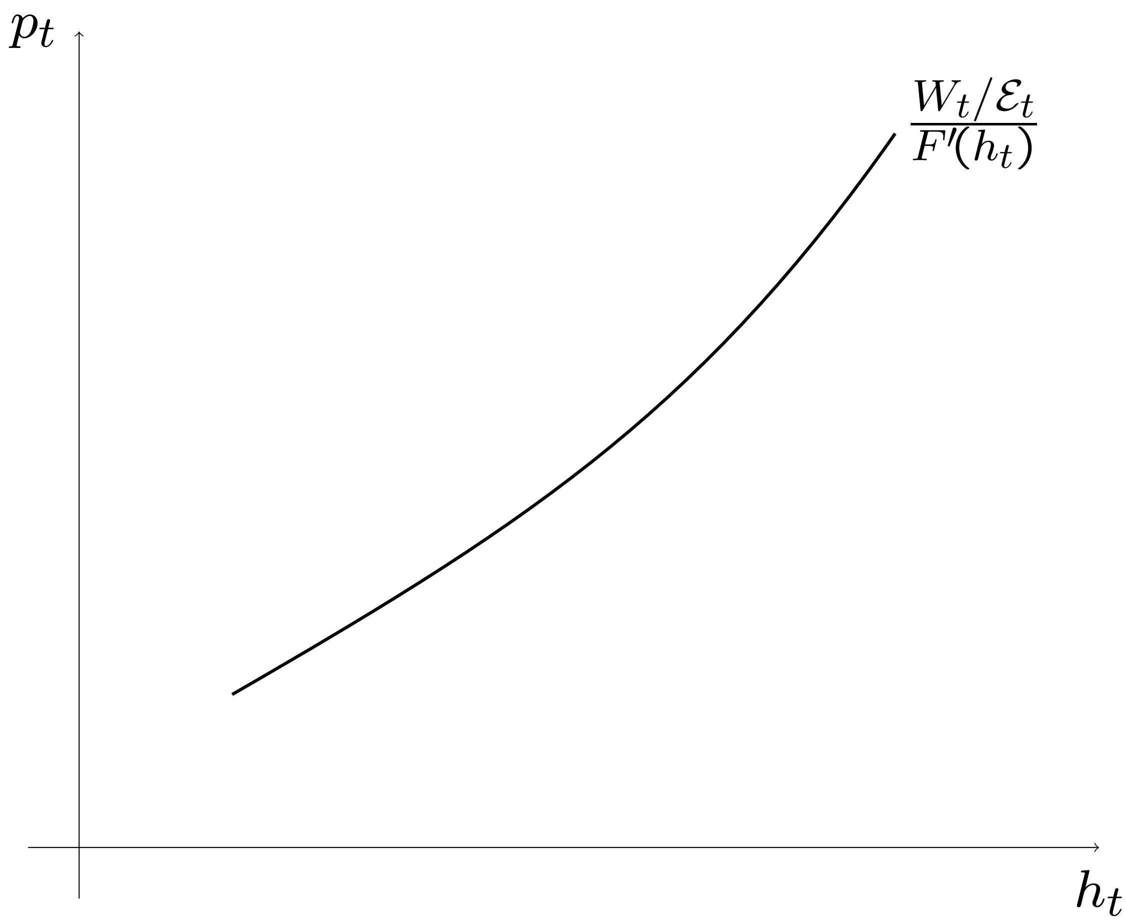
$$p_t \equiv \frac{P_t^N}{P_t^T},$$

denote the relative price of nontradables in terms of tradables. We can then write the optimality condition of firms, equation (4), as

$$p_t = \frac{W_t/\mathcal{E}_t}{F'(h_t)}. \tag{5}$$

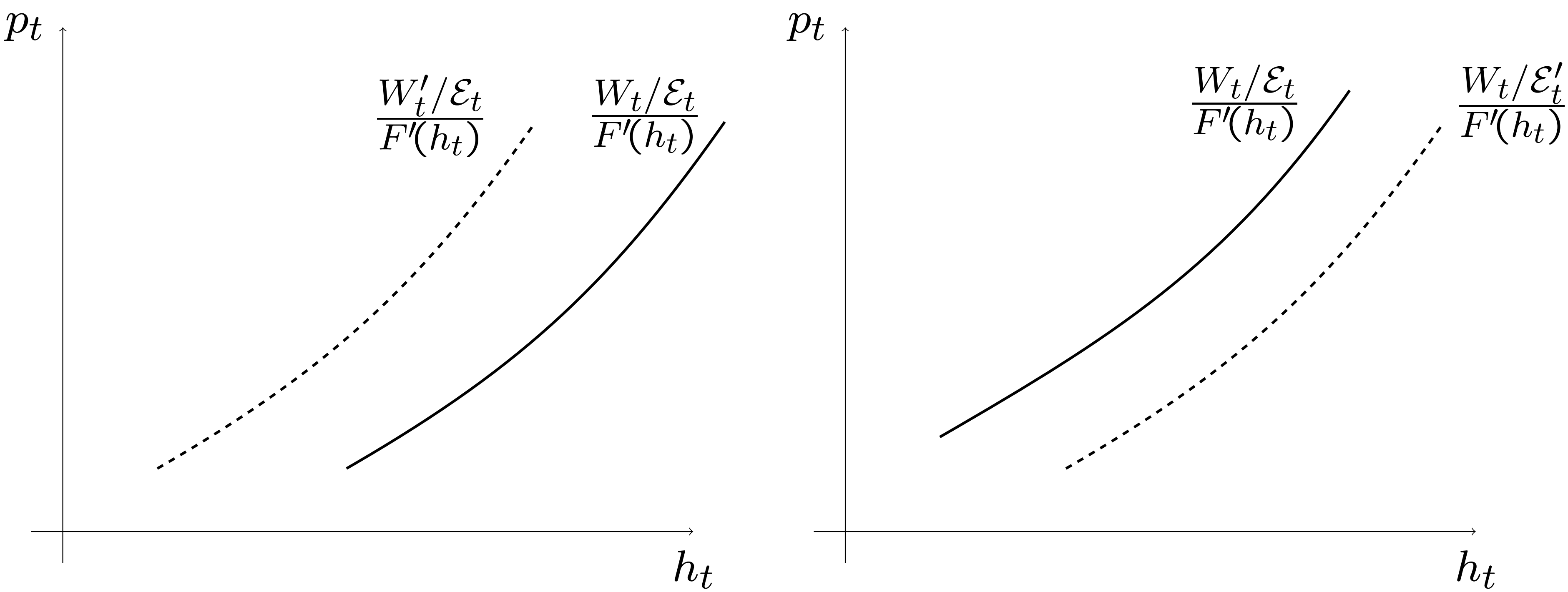
We call equation (5) the *supply schedule* of nontradable goods and depict in the next slide.

The Supply Schedule: $p_t = \frac{W_t/\mathcal{E}_t}{F'(h_t)}$



Notes. The supply schedule is an increasing relationship between the relative price of nontradables in terms of tradables, p_t, and employment, h_t. All other things equal, an increase in p_t opens up a positive gap between marginal revenue and marginal cost, $p_t - (W_t/\mathcal{E}_t)/F'(h_t)$, which induces firms to expand production and employment until the gap disappears.

Shifters of the Supply Schedule



Notes. The left panel shows that an increase in the nominal wage from W_t to $W_t' > W_t$, holding constant the nominal exchange rate, $\mathcal{E}_t$, shifts the supply schedule up and to the left. Given $\mathcal{E}_t$, an increase in W_t raises marginal cost, which discourages production and employment for any given relative price, p_t. The right panel shows that holding constant the nominal wage, W_t, an increase in $\mathcal{E}_t$ to $\mathcal{E}_t' > \mathcal{E}_t$ (a depreciation of the domestic currency) shifts the supply schedule down and to the right. Given W_t, a depreciation lowers the real wage, which induces firms to expand output and employment at any given level of p_t.

Summary of the Supply Schedule

• The supply schedule is a positive relationship between the relative price of the nontraded good and the level of employment necessary to produce the firm's desired supply of nontradables.

• Holding the nominal exchange rate constant, an increase in the nominal wage, W_t, pushes the supply schedule up and to the left.

• Holding the nominal wage constant, a depreciation of the domestic currency—an increase in $\mathcal{E}_t$—shifts the supply schedule down and to the right.

Households' Preferences

The utility function is

$$\ln C_1 + \beta \ln C_2, \tag{6}$$

Consumption is a composite of tradable consumption, C_t^T, and nontradable consumption, C_t^N:

$$C_t = (C_t^T)^\gamma (C_t^N)^{1-\gamma}, \tag{7}$$

for $t = 1, 2$.

Labor Supply

Each period $t = 1, 2$, the household supplies inelastically a constant number of hours of work $\bar{h}$.

However, sometimes there is unemployment and workers get to work less than $\bar{h}$ hours, so that we have

$$h_t \leq \bar{h}, \tag{8}$$

where h_t is the number of hours actually worked. Workers take h_t as given, as it depends on labor market conditions, which they don't control.

Households' Budget Constraints

The household's budget constraint in period 1 is

$$P_1^T C_1^T + P_1^N C_1^N + \mathcal{E}_1 B_1 = \mathcal{E}_1 (1+r_0) B_0 + P_1^T Q_1^T + W_1 h_1 + \Pi_1,$$

where B_0 denotes bonds purchased in period 0 paying the interest rate r_0, and B_1 denotes bonds purchased in period 1 paying the world interest rate r^*. Bonds are denominated in foreign currency. The budget constraint in period 2 is

$$P_2^T C_2^T + P_2^N C_2^N = P_2^T Q_2^T + W_2 h_2 + \Pi_2 + (1+r^*) \mathcal{E}_2 B_1,$$

To obtain the intertemporal budget constraint, combine the budget constraints in periods 1 and 2 to eliminate B_1,

$$C_1^T + p_1 C_1^N + \frac{C_2^T + p_2 C_2^N}{1+r^*} = \bar{Y}, \tag{9}$$

where

$$\bar{Y} \equiv (1+r_0) B_0 + Q_1^T + \frac{W_1}{\mathcal{E}_1} h_1 + \frac{\Pi_1}{\mathcal{E}_1} + \frac{Q_2^T + W_2/\mathcal{E}_2 h_2 + \Pi_2/\mathcal{E}_2}{1+r^*}$$

represents lifetime wealth, which the household takes as given.

The Household's Optimization Problem

Using (7), for $t = 1, 2$, and (9) to eliminate C_t, for $t = 1, 2$, and C_2^T from the lifetime utility function (6) yields

$$\gamma \ln C_1^T + (1-\gamma) \ln C_1^N + \beta\gamma \ln \left[(1+r^*)\bar{Y} - p_2 C_2^N - (1+r^*)(C_1^T + p_1 C_1^N) \right] + \beta(1-\gamma) \ln C_2^N.$$

The household chooses C_1^T, C_1^N, and C_2^N to maximize this expression, taking as given $\bar{Y}$, p_1, p_2, and r^*.

Optimality Conditions

The optimality conditions with respect to C_1^T, C_1^N, and C_2^N are, respectively,

$$\frac{C_2^T}{C_1^T} = \beta(1 + r^*), \tag{10}$$

$$\frac{1-\gamma}{C_1^N} = \beta\gamma(1 + r^*)\frac{p_1}{C_2^T}, \tag{11}$$

$$\frac{C_2^N}{C_2^T} = \frac{1-\gamma}{\gamma}\frac{1}{p_2}. \tag{12}$$

Combine optimality conditions (10) and (11) to get

$$\frac{C_1^N}{C_1^T} = \frac{1-\gamma}{\gamma}\frac{1}{p_1}, \tag{13}$$

which says that if p_t increases, the household consumes relatively less nontradables and more tradables.

Market Clearing

In equilibrium, the market for nontraded goods must clear;

$$C_t^N = F(h_t), \tag{14}$$

for $t = 1, 2$.

The Intertemporal Resource Constraint

Using the market-clearing condition (14) and the definition of firms' profits (2) to eliminate C_t^N and Π_t from the intertemporal budget constraint (9) yields the economy-wide resource constraint

$$C_1^T + \frac{C_2^T}{1+r^*} = (1+r_0)B_0 + Q_1^T + \frac{Q_2^T}{1+r^*}, \tag{15}$$

which says that the present discounted value of tradable consumption must equal the sum of the initial asset position and the present discounted value of the endowment of tradable goods.

Equilibrium Consumption of Tradables

Using (10) to eliminate C_2^T from (15) yields the equilibrium value of C_1^T,

$$C_1^T = \frac{1}{1+\beta}\left[(1+r_0)B_0 + Q_1^T + \frac{Q_2^T}{1+r^*}\right]. \tag{16}$$

This is intuitive: consumption decreases with the interest rate and increases with the endowments and the initial wealth. We summarize equation (16) by writing

$$C_1^T = C^T(\underset{-}{r^*}, \underset{+}{Q_1^T}, \underset{+}{Q_2^T}, \underset{+}{(1+r_0)B_0}). \tag{17}$$

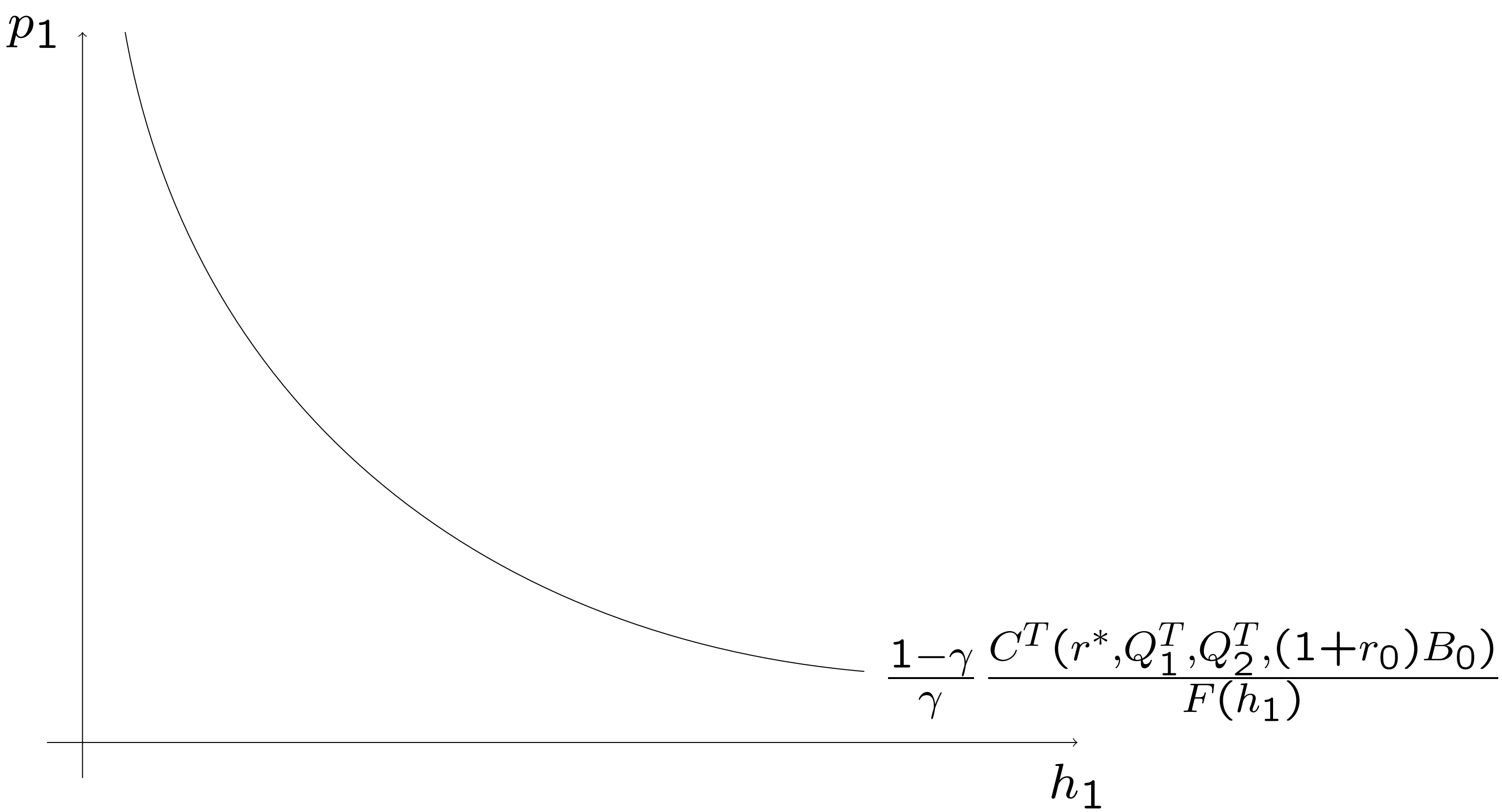
The Demand Schedule

Use (17) and (14) to eliminate C_1^T and C_1^N from (13), to obtain

$$p_1 = \frac{1-\gamma}{\gamma} \frac{C^T(r^*, Q_1^T, Q_2^T, (1+r_0)B_0)}{F(h_1)}. \tag{18}$$

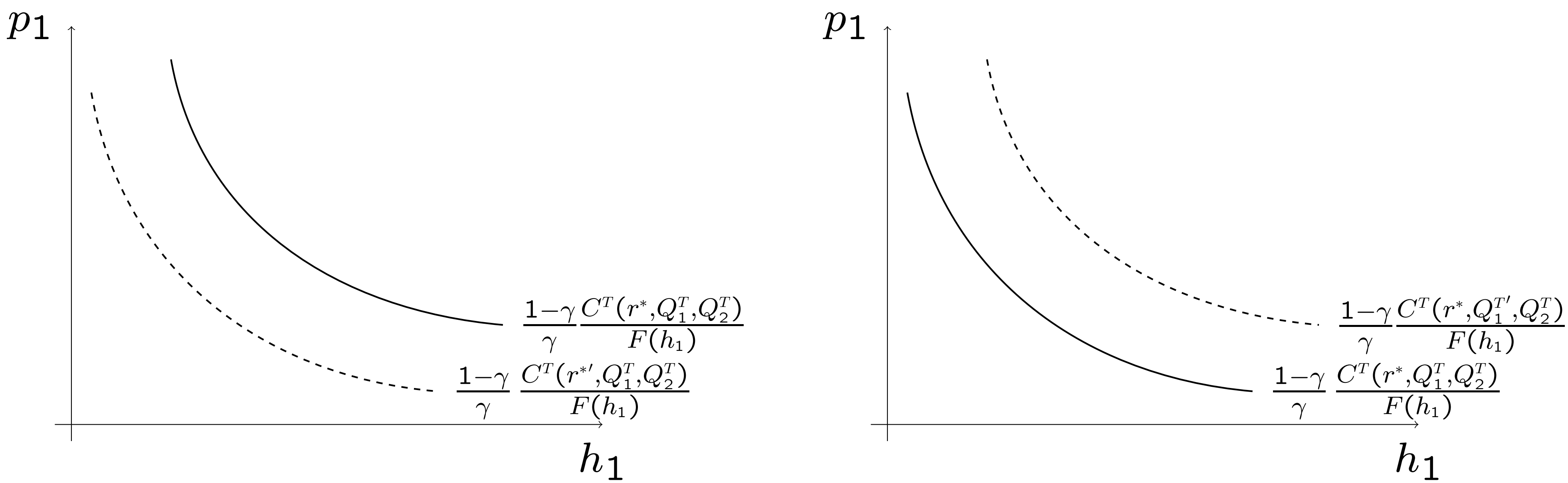
This is the demand schedule and is depicted in the next slide. In words, the demand schedule says that an increase in p_1 causes a fall in the demand for nontradable goods, which requires a reduction in employment to clear the market for nontradable goods.

The Demand Schedule: $p_1 = \frac{1-\gamma}{\gamma}\frac{C^T}{F(h_1)}$



Notes. The figure depicts the demand schedule in period 1. Holding constant r^*, Q_1^T, Q_2^T, and $(1+r_0)B_0$, the higher is the relative price of nontradables, p_1, the lower will be the demand for nontradables, C_1^N. If the nontradable market is in equilibrium, a lower demand for nontradables implies lower nontradable output, $F(h_1)$, and hence lower employment, h_1.

Shifters of the Demand Schedule



Notes. The left panel shows that an increase in the world interest rate from r^* to $r^{*\prime} > r^*$ shifts the demand schedule down and to the left. By the intertemporal substitution effect, a higher interest rate reduces the demand for tradable goods, C_1^T, which, for every level of the relative price p_1 lowers the demand for nontradable goods, C_1^N, and thereby the implied demand for labor, h_1.

The right panel shows that an increase in the period-1 endowment of tradable goods from Q_1^T to $Q_1^{T\prime} > Q_1^T$ shifts the demand schedule up and to the right. By the income effect, an increase in the endowment increases the demand for tradable and nontradable goods for every level of the relative price p_1 and thereby the demand for labor, h_1. A future expected increase in the endowment of tradables Q_2^T (not depicted) also shifts the demand schedule up and to the right for the same reasons.

Summary of the Demand Schedule

• The demand schedule is a negative relationship between the relative price of the nontraded good and the level of employment necessary to produce the desired demand for nontradables.

• An increase in the world interest rate r^* shifts the demand schedule down and to the left.

• An increase in the current or future endowment of tradables (Q_1^T or Q_2^T) shifts the demand schedule up and to the right.

The Labor Market Slackness Condition

Earlier, we assumed that the nominal wage is downwardly rigid by imposing the constraint (1). We now impose two additional assumptions about the functioning of the labor market:

• When there is involuntary unemployment ($h_t < \bar{h}$), the lower bound on wages is binding ($W_t = W_{t-1}$).

• If the wage constraint is slack ($W_t > W_{t-1}$), then the economy is at full employment ($h_t = \bar{h}$).

These 2 assumptions can be formalized by writing

$$(W_t - W_{t-1})(\bar{h} - h_t) = 0, \tag{19}$$

which we will call the *labor market slackness condition*.

Equilibrium in the TNT-DNWR Model

Summarizing, the equilibrium in the TNT-DNWR model are values of C_t^T, h_t, W_t, and p_t, for $t = 1, 2$, satisfying

$$C_1^T = \frac{1}{1+\beta}\left[(1+r_0)B_0 + Q_1^T + \frac{Q_2^T}{1+r^*}\right], \tag{20}$$

$$C_2^T = \beta(1+r^*)C_1^T, \tag{21}$$

$$p_t = \frac{1-\gamma}{\gamma}\frac{C_t^T}{F(h_t)}, \tag{22}$$

$$p_t = \frac{W_t/\mathcal{E}_t}{F'(h_t)}, \tag{23}$$

$$h_t \leq \bar{h}, \tag{24}$$

$$W_t \geq W_{t-1}, \tag{25}$$

$$(W_t - W_{t-1})(\bar{h} - h_t) = 0, \tag{26}$$

given $(1+r_0)B_0$, W_0, Q_1^T, Q_2^T, r^*, and an exchange rate policy $\mathcal{E}_1$, $\mathcal{E}_2$.

Equilibrium Values of the Trade Balance, the Current Account, and the Net International Investment Position

Having obtained the equilibrium values of C_t^T, the equilibrium values of the variables defining the external accounts are easily obtained:

• The trade balance is the difference between tradable output and tradable consumption:

$$TB_t = Q_t^T - C_t^T. \tag{27}$$

• The net foreign asset position in period 1, B_1, is

$$B_1 = (1 + r_0)B_0 + TB_1. \tag{28}$$

And $B_2 = 0$. Why?

• The current account in period t, for $t = 1, 2$, equals the change in the country's net foreign asset position,

$$CA_t = B_t - B_{t-1}. \tag{29}$$

Adjustment to Shocks with a Fixed Exchange Rate

Why is it Important to Study Fixed Exchange Rate?

Probably the main reason is that currency pegs, in their different varieties, are the most prevalent exchange rate arrangement.

Varieties of Currency Pegs

- Classic peg: the central bank guarantees convertibility of the domestic currency with a foreign currency at a fixed exchange rate (e.g., Austria, Argentina under its Convertibility Law 1991-2001).
- Crawling peg: the central bank guarantees convertibility at a preannounced exchange rate schedule (e.g., Nicaragua, the *tablitas* in the southern cone of Latin America in the late 1970s).
- Monetary union: a group of countries share a common currency (e.g., the eurozone: the exchange rate between the Portuguese currency (the euro) and the German currency (the euro) is 1).
- Dollarization: a country adopts another country's currency (Ecuador, El Salvador, Panama all adopted the U.S. dollar)

Fear of Floating: most countries who claim to float *(de jure floaters)* in fact keep the exchange rate stable *(de facto peggers)*. This empirical finding is due to Guillermo Calvo and Carmen Reinhart (*QJE* 2002). (The former is a Columbia professor and the latter a Columbia Ph.D.!)

A Fixed Exchange Rate Regime

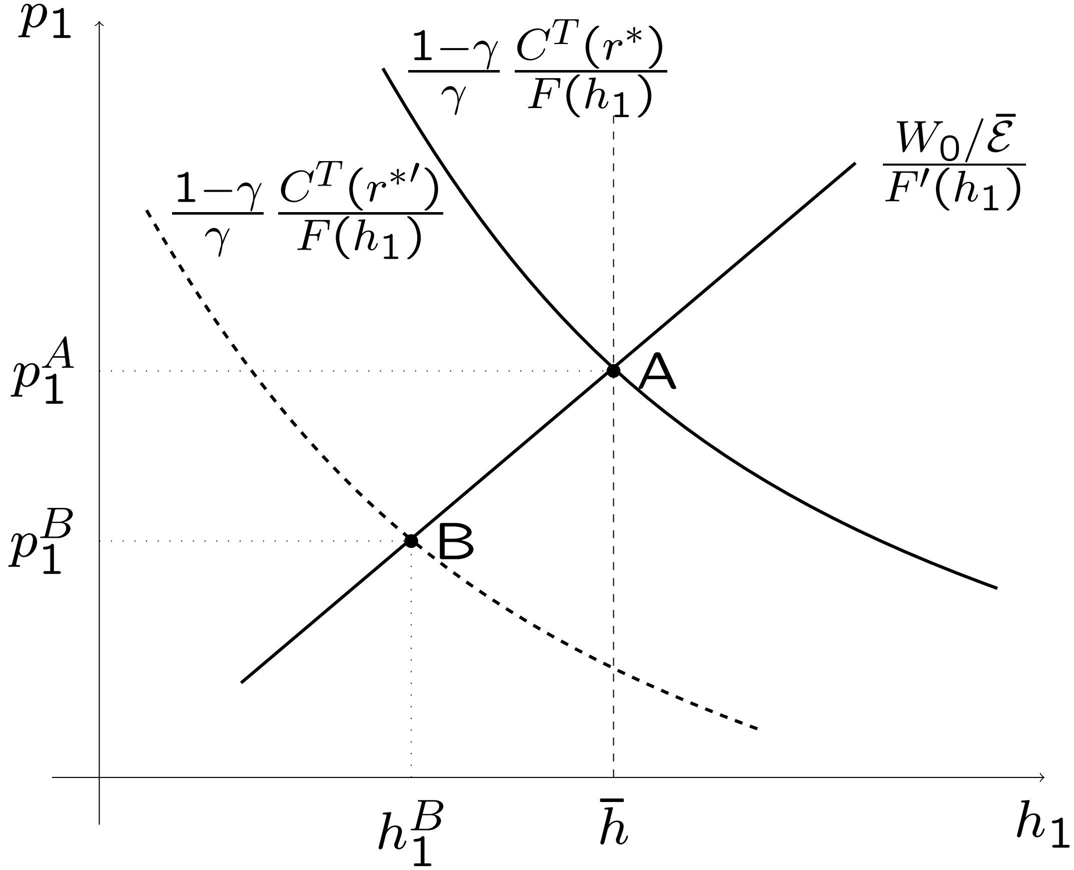
Suppose that the central bank pegs the exchange rate at a constant value $\bar{\mathcal{E}}$; that is,

$$\mathcal{E}_t = \bar{\mathcal{E}}.$$

To effectively achieve a fixed exchange rate, the central bank must stand ready to buy or sell any quantity of foreign currency desired by the public.

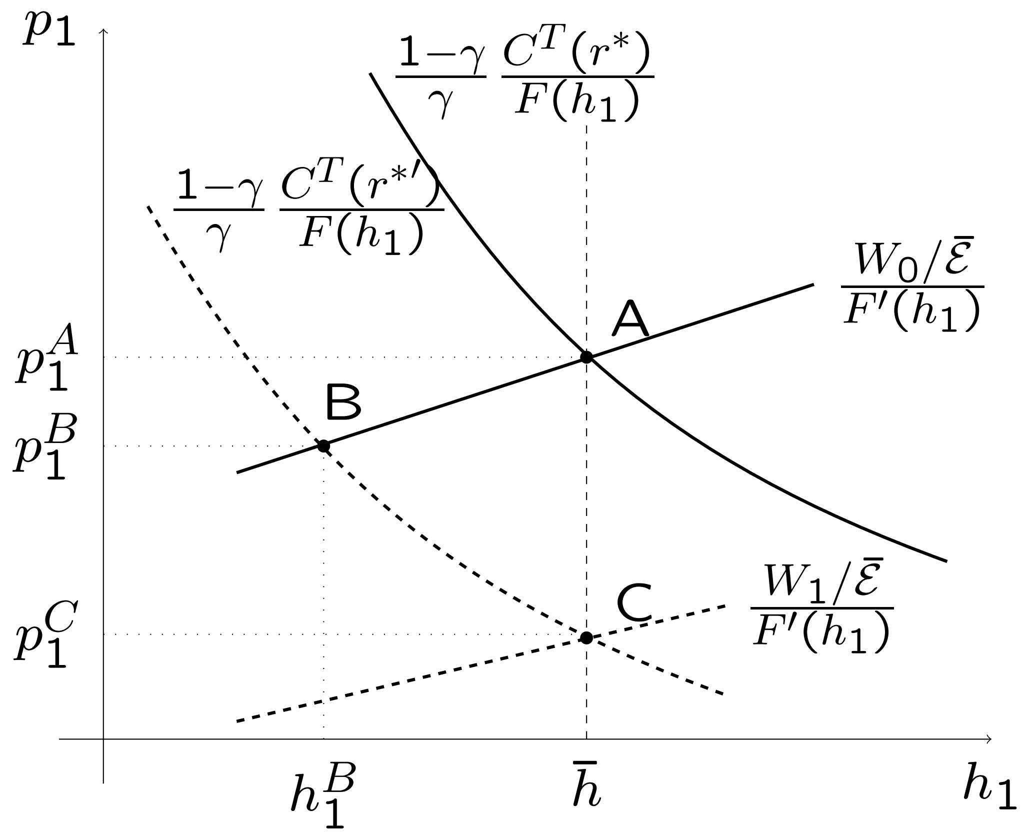
Question: How does the economy adjust to different shocks under a fixed exchange rate regime and downward nominal wage rigidity?

Adjustment to an Increase in the World Interest Rate under a Fixed Exchange Rate



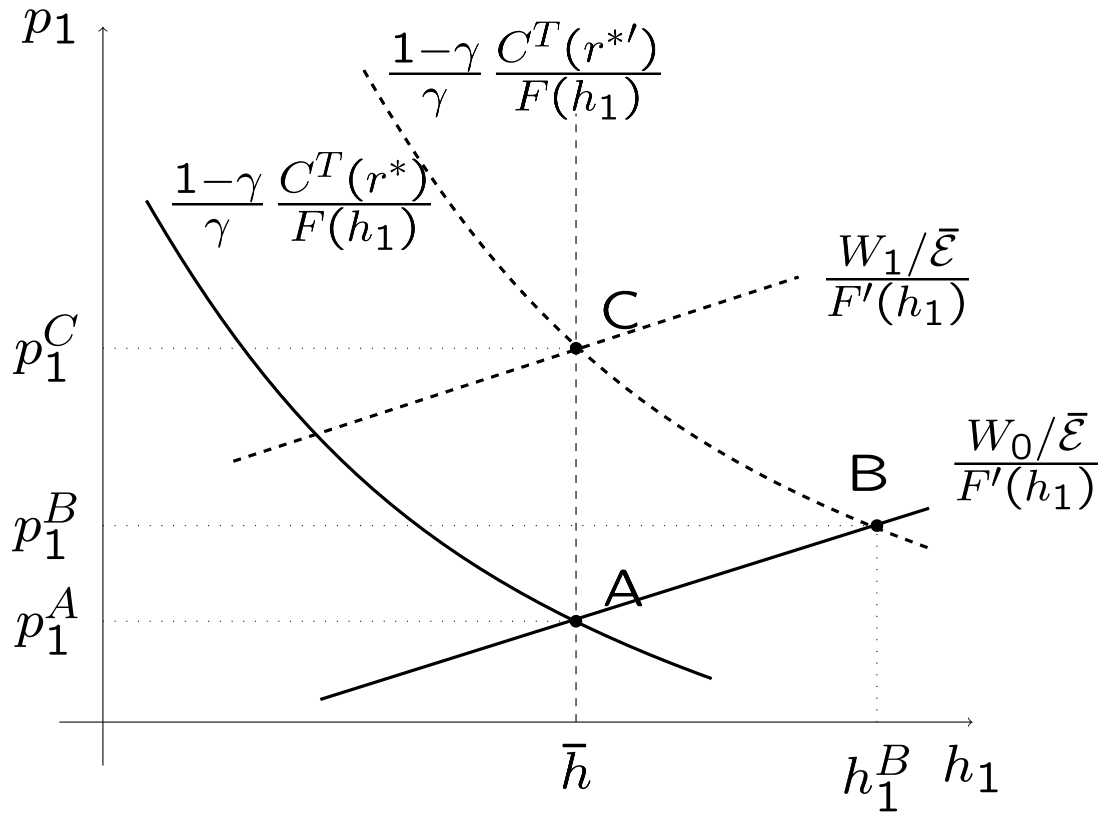
Notes. Prior to the increase in the world interest rate from r^* to $r^{*\prime} > r^*$, the equilibrium is at point A, where there is full employment, $h_1 = \bar{h}$. The nominal wage is W_0 and the nominal exchange rate is fixed at $\bar{\mathcal{E}}$. The increase in r^* shifts the demand schedule down and to the left. The supply schedule is unchanged, however, because the combination of downward nominal wage rigidity and a fixed exchange rate prevents a decline in the real wage, $W_0/\bar{\mathcal{E}}$. As a result, unemployment in the amount $\bar{h} - h_1^B$ emerges at the new equilibrium, point B.

Adjustment to an Increase in the World Interest Rate under Wage Flexibility



Notes. Prior to the increase in the world interest rate the equilibrium is at point A, where the labor market operates at full employment. The increase in the world interest rate from r^* to $r^{*\prime}$ shifts the demand schedule down and to the left. Under downward nominal wage rigidity the equilibrium is at point B, where the economy suffers involuntary unemployment. Under wage flexibility, the nominal wage falls from W_0 to $W_1 < W_0$, shifting the supply schedule down and to the right. The new equilibrium is at point C, where the economy continues to operate at full employment, and the relative price of nontradables is lower than at the pre-shock equilibrium or at the equilibrium with downward nominal wage rigidity, $p_1^C < p_1^B < p_1^A$.

Asymmetric Adjustment: A Decrease in the World Interest Rate under a Fixed Exchange Rate



Notes. The nominal exchange rate is fixed at $\bar{\mathcal{E}}$. Prior to the decrease in the world interest rate from r^* to $r^{*\prime} < r^*$, the equilibrium is at point A, where there is full employment, $h_1 = \bar{h}$, and the nominal wage is W_0. The fall in r^* shifts the demand schedule up and to the right. Absent an increase in nominal wages, the equilibrium would be at point B, where labor demand exceeds labor supply, $h_1^B > \bar{h}$. As a result, wages will rise until the excess demand is eliminated. The increase in wages shifts the supply schedule up and to the left. The new equilibrium is at point C, where there is full employment, $h_1 = \bar{h}$, the nominal wage rate is equal to $W_1 > W_0$, and the relative price of nontradables is higher, $p_1^C > p_1^A$.

Summary of Adjustment to World Interest Rate Shocks Under a Fixed Exchange Rate

• An increase in r^* reduces the demand for tradable and nontradable goods, C_t^T and C_t^N.

• The tradable goods that cannot be sold domestically, are exported, $TB_1 = Q_1^T - C_1^T$ goes up.

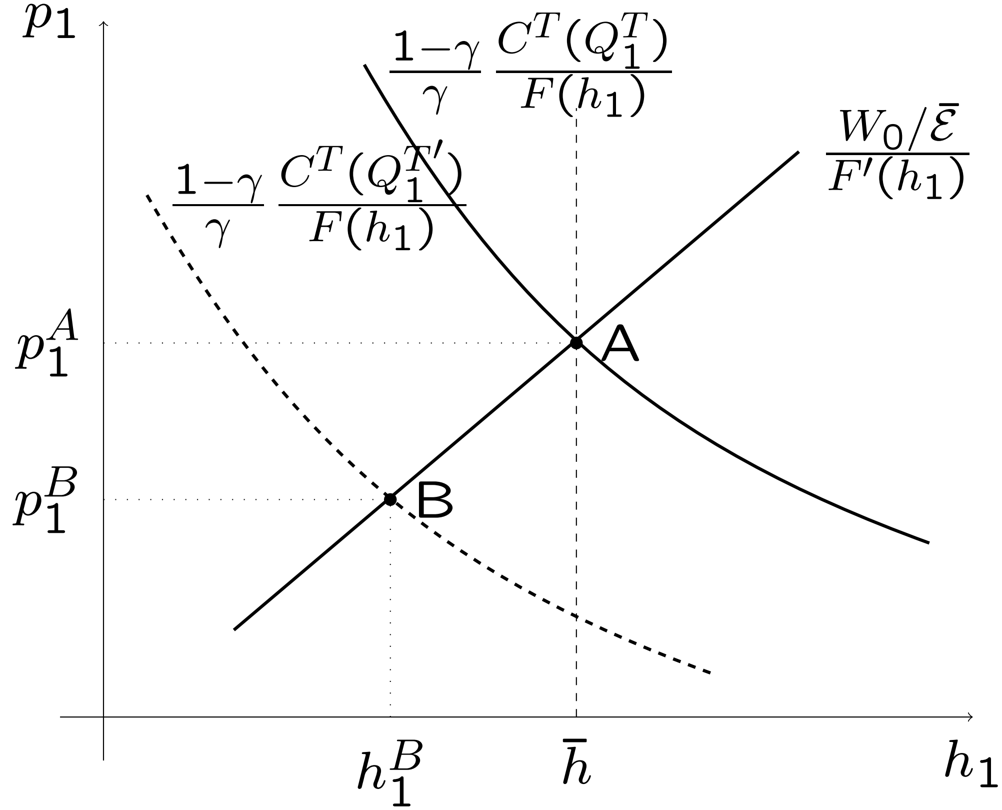
• By contrast, the fall in demand causes unemployment in the nontraded sector, $\bar{h} - h_1 > 0$: The relative price of nontradables, p_1, does not fall enough because the labor cost—the real wage $W_1/\mathcal{E}_1$—stays too high. In turn, the real wage doesn't fall because the nominal wage is downwardly rigid and the nominal exchange rate is pegged.

• The combination of downward nominal wage rigidity and a fixed exchange rate causes downward rigidity in the real wage.

• Under flexible wages, the fall in aggregate demand caused by the increase in r^* is followed by a fall in the nominal (and real) wage large enough to maintain full employment. Also, the relative price of nontradables falls (i.e., the real exchange rate depreciates) enough to induce the necessary expenditure switch in favor of nontradables—the fall in p_1 is larger than under wage rigidity.

• With downwardly rigid nominal wages, the economy adjusts asymmetrically to increases and decreases in the interest rate: most importantly, the real wage increases when r^* falls, but does not fall when r^* increases.

Adjustment to a Fall in Tradable Output under a Fixed Exchange Rate



Notes. Prior to the fall in tradable output from Q_1^T to $Q_1^{T\prime} < Q_1^T$, the equilibrium is at point A, where there is full employment, $h_1 = \bar{h}$. The nominal wage is W_0 and the nominal exchange rate is fixed at $\bar{\mathcal{E}}$. The decline in Q_1^T shifts the demand schedule down and to the left. The supply schedule is unchanged, however, because the combination of downward nominal wage rigidity and a fixed exchange rate prevents a decline in the real wage, $W_0/\bar{\mathcal{E}}$. As a result, unemployment in the amount $\bar{h} - h_1^B$ emerges at the new equilibrium, point B. The effects on h_1, W_1, and p_1 of a fall in the future endowment (Q_2^T) or a fall in the current or future terms of trade (TT_1 or TT_2) (not shown) are qualitatively identical.

Summary of Adjustment to Output and Terms of Trade Shocks under a Fixed Exchange Rate

• A fall in the endowment of tradables (Q_1^T) makes households poorer and depresses the demand for tradable and nontradable goods.

• The fall in demand causes involuntary unemployment, because neither the nominal wage nor the nominal exchange rate can adjust to make the real wage fall to the level that clears the labor market.

• Because labor costs remain high, firms cannot lower prices, so there is insufficient expenditure switching away from tradables and toward nontradables.

• The effects on h_1, W_1, and p_1 of a future expected fall in the endowment (Q_2^T) or of a current or future fall in the terms of trade (TT_1 or TT_2) (not shown) are qualitatively identical to those of a fall in the current endowment.

Volatility and Average Unemployment

We saw that under fixed exchange rates, shocks can have asymmetric effects.

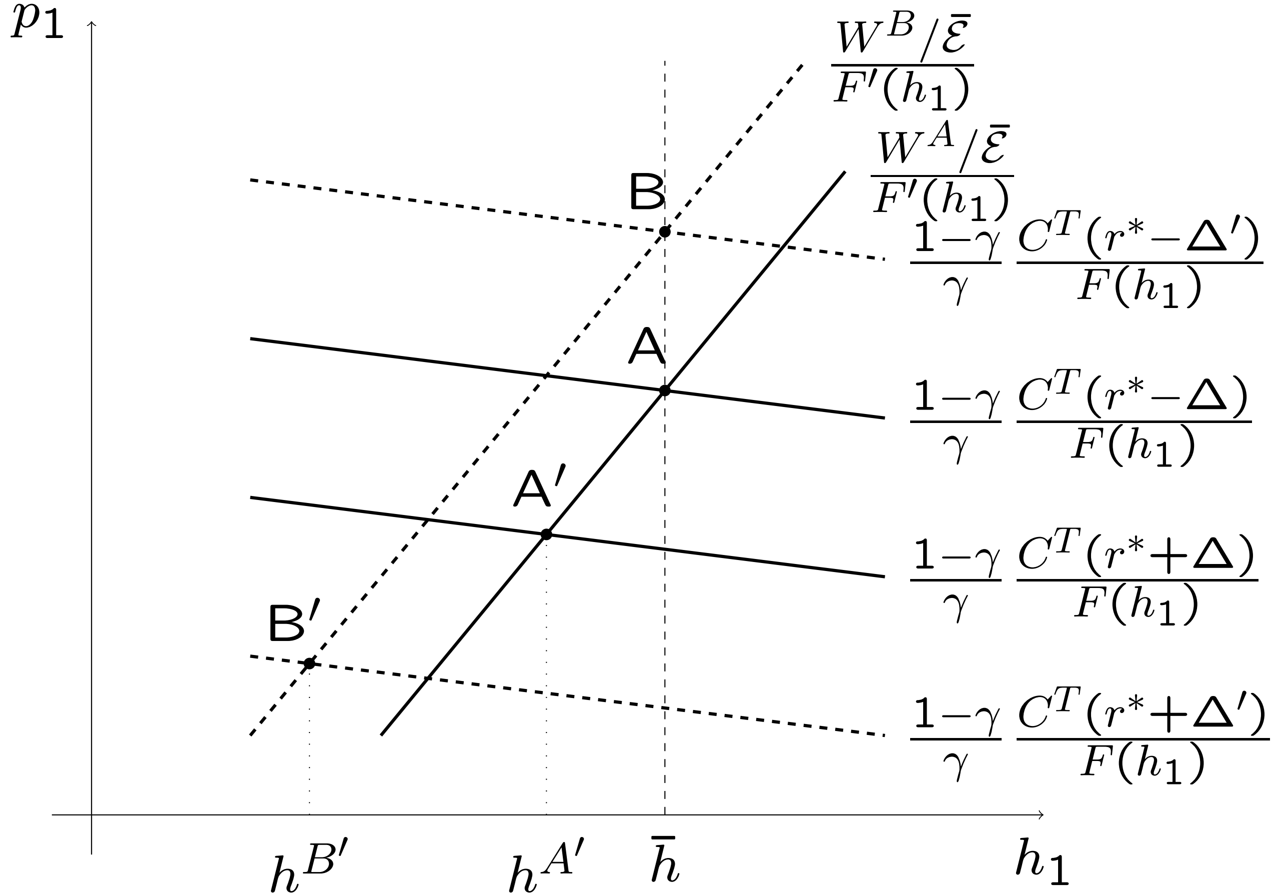
For example, starting from full employment ($h_1 = \bar{h}$), an increase in r^* causes unemployment ($h_1 < \bar{h}$), but a fall in r^* preserves full employment ($h_1 = \bar{h}$).

This means that fluctuations in the world interest rate cause unemployment on average: if h_t is sometimes lower than $\bar{h}$ and sometimes equal to $\bar{h}$, then on average it is below $\bar{h}$.

Furthermore, the larger the amplitude of the movements in r^* are, the larger the average level of unemployment will be.

In general, we have that under fixed exchange rates a second moment (the standard deviation of shocks) has first-order effects unemployment (on average unemployment). The next slide provides a graphical illustration.

Volatility and Average Unemployment under a Fixed Exchange Rate



Notes. The figure illustrates the effect of an increase in volatility of the world interest rate on average unemployment. In the low volatility environment, the interest rate fluctuates between $r^* + \Delta$ and $r^* - \Delta$, and the equilibrium level of employment fluctuates between $h^{A'}$ and $\bar{h}$. In the high volatility environment, the interest rate fluctuates between $r^* + \Delta'$ and $r^* - \Delta'$, where $\Delta' > \Delta$, and the equilibrium level of employment between $h^{B'}$ and $\bar{h}$. The average rate of unemployment is larger in the high volatility environment.

Adjustment to Shocks with a Floating Exchange Rate

A Floating Exchange Rate

Under a flexible or floating exchange rate regime, the nominal exchange rate can change over time.

There is an infinite number of floating exchange rate regimes.

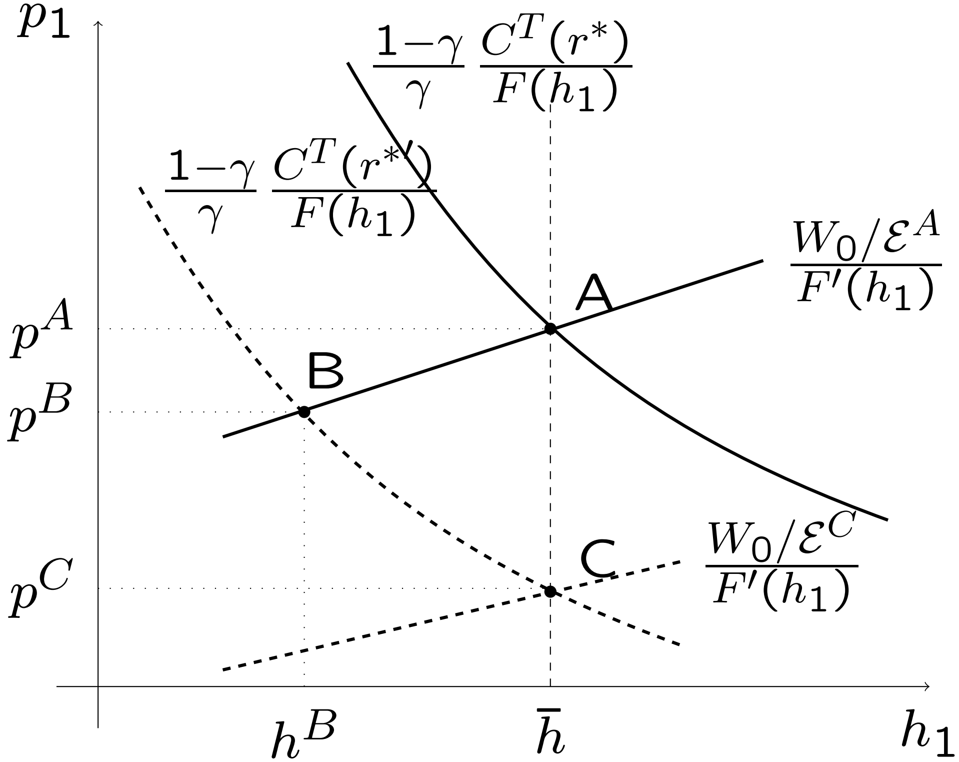
We focus on a particular member of this large family, in which the central bank aims to achieve full employment and price stability.

A *dual mandate* of this type is common for central banks around the world.

Core inflation
Central banks often focus on a measure of inflation that excludes food and energy, whose prices are too volatile. Food and energy goods are typically internationally traded.

We will therefore assume that the price the central bank aims to stabilize is the price of the nontradable good, P_t^N.

Adjustment to an Increase in the World Interest Rate with a Floating Exchange Rate



Notes. Prior to the increase in the world interest rate the equilibrium is at point A, where the labor market operates at full employment, the nominal wage is W_0, the nominal exchange rate is $\mathcal{E}^A$, and the nominal price of nontradables is $W_0/F'(\bar{h})$. The increase in the world interest rate from r^* to $r^{*\prime} > r^*$ shifts the demand schedule down and to the left. Absent a change in the exchange rate, the equilibrium would be at point B, where employment is $h^B < \bar{h}$. The central bank can achieve its objectives of full employment and price stability by depreciating the exchange rate to $\mathcal{E}^C > \mathcal{E}^A$. At point C, $h_1 = \bar{h}$ and $P_1^N = W_0/F'(\bar{h})$, which are the same values as at point A. The adjustment to other external shocks such as a fall in the terms of trade (TT_1 or TT_2) is similar.

Effect of the Currency Depreciation on the Price Level

(Terminology: we use the terms depreciation or devaluation to refer to an increase in $\mathcal{E}_t$)

The graph on the previous slide shows that a depreciation of the domestic currency from $\mathcal{E}^A$ to $\mathcal{E}^C$ preserves full employment ($h_1 = \bar{h}$).

What about P_1^N? Recall the firm's optimality condition (value of the marginal product of labor = wage rate):

$$P_1^N F'(\bar{h}) = W_0$$

Since neither employment nor the nominal wage changed, we have that P_1^N is also unchanged. So the currency depreciation preserves price stability.

In sum, we have that the effects of an increase in the world interest rate under a floating exchange rate are:

$r^* \uparrow \Rightarrow h_1$ unchanged; P_1^N unchanged; $C_1^T \downarrow$; $TB_1 = Q_1^T - C_1^T \uparrow$.

Adjustment to Tradable Output Shocks and Terms of Trade Shocks Under a Floating Exchange rate Regime

The effect of a fall in Q_t^T, or a fall in TOT_t, for $t = 1, 2$, on unemployment and the price level under a floating exchange rate regime are similar to the effect of an increase in the world interest rate:

A currency depreciation in the right amount preserves full employment and price stability.

Properties of the Exchange Rate Policy under External Shocks

• Movements in the exchange rate achieve both full employment and price stability.

• In response to a negative external shock, too little depreciation results in unemployment and too much depreciation results in inflation.

• The larger the negative external shock, the larger the necessary depreciation will be.

• A currency depreciation cannot completely avoid a macroeconomic contraction: it cannot avoid a reduction in the demand for tradables.

• A positive correlation between contractions and currency depreciations need not be an indication that devaluations are contractionary. If the observed contractions are due to external shocks, then the correct conclusion may be that contractions are devaluatory.

Supply Shocks, the Inflation-Unemployment Trade-off, and Stagflation

Thus far, we have analyzed shocks that shift the demand schedule.

Consider now shocks that shift the supply schedule.

Consider the production function

$$Q_1^N = A_1 h_1^\alpha$$

with $\alpha \in (0,1)$. Here, A_1 is a productivity factor determined by the state of technology or government regulation.

Consider a negative productivity shock in period 1; that is, a reduction in A_1. Suppose that prior to the shock, the nominal wage is $W_1 = W_0$.

The Inflation-Unemployment Trade-off

With this production function, optimality condition (3) becomes

$$P_1^N \alpha A_1 h_1^{\alpha-1} = W_0. \tag{30}$$

Suppose that prior to the shock, the economy is at full employment, $h_1 = \bar{h}$ and recall that the nominal wage is downwardly rigid. It is clear from (30) that

- If the government favors full employment, then the fall in A_1 requires an increase in P_1^N, so the government must sacrifice the goal of price stability.

- If instead the government favors price stability (i.e., keeping P_1^N unchanged), then the fall in A_1 causes a fall in h_1, so the government must sacrifice the goal of full employment (recall that $\alpha \in (0, 1)$).

⇒ The government faces an inflation-unemployment trade-off: When the economy experiences simultaneously unemployment and inflation, it is said to suffer from *stagflation*.

Adjustment of the Exchange Rate to Supply Shocks

Once the government chooses the mix of inflation and unemployment it wishes to have, there is an exchange rate policy that makes it happen: With our new production function, the demand schedule (18) becomes

$$\frac{P_1^N}{\mathcal{E}_1} = \frac{1-\gamma}{\gamma} \frac{C^T(r^*, Q_1^T, Q_2^T)}{A_1 h_1^\alpha}. \tag{31}$$

• If the government chooses to maintain full employment ($h_1 = \bar{h}$), then in response to the fall in A_1 the nominal exchange rate stays unchanged.* (Recall that in this case P_1^N increases in the same proportion as A_1 falls.)

• If the government chooses to maintain price stability (P_1^N unchanged), then the fall in A_1 requires an exchange rate appreciation (a fall in $\mathcal{E}_1$). (Recall that in this case h_1 falls.)

*The result that the nominal exchange rate is unchanged is a result of the assumption of log utility and a Cobb Douglas production function. Exercise 13.5 shows that if one relaxes those assumptions then the nominal exchange rate can either de- or appreciate.

The Monetary Policy Trilemma

The central bank can achieve simultaneously only two of the following three things:
(1) A fixed exchange rate.
(2) Monetary autonomy (set the nominal interest rate).
(3) Free capital mobility.

To see this notice that under capital mobility

$$1 + i = \frac{\mathcal{E}_2}{\mathcal{E}_1}(1 + r^*), \tag{32}$$

where i =domestic nominal interest rate. If (1) and (3) hold, then (32) determines i. If (1) and (2) hold, then (32) will in general not hold. And if (2) and (3) hold, then (32) determines $\mathcal{E}_2/\mathcal{E}_1$.

Exchange Rate Overshooting

Under certain monetary arrangements, the nominal exchange rate tends to overreact to movements in monetary policy. This property is known as *exchange rate overshooting*.

We wish to analyze what happens with the nominal exchange rate in the short and the long runs when the central bank reduces the quantity of money.

If the effect on the exchange rate is more pronounced in the short than in the long run, we say that it overshoots.

Suppose the demand for money is proportional to expenditure in nontradables:

$$M_t = P_t^N C_t^N. \tag{33}$$

Using (3) and (14) and assuming that $F(h_t) = h_t^\alpha$, we can write (33) as

$$M_t = \frac{1}{\alpha} W_t h_t. \tag{34}$$

Suppose that the central bank cuts the money supply by a factor λ,

$$M_t' = (1 - \lambda) M_t.$$

Suppose also that prior to the monetary contraction $h_1 = \bar{h}$ and $W_1 = W_0$. So

$$M_1 = \frac{1}{\alpha} W_0 \bar{h}. \tag{35}$$

Let's analyze the short and long run effects on the exchange rate separately.

Short Run

Because of DNWR, we have that

$$\frac{h_1'}{h_1} = 1 - \lambda \Rightarrow \text{ unemployment} \tag{36}$$

where $'$ denotes after the shock. From (3),

$$\frac{P_1^{N\prime}}{P_1^N} = \left(\frac{h_1'}{h_1}\right)^{1-\alpha} = (1-\lambda)^{1-\alpha} < 1 \Rightarrow \text{ core deflation} \tag{37}$$

Consider the demand schedule

$$p_t = \frac{1-\gamma}{\gamma}\left(\frac{C^T(r^*, Q_1^T, Q_2^T)}{h_t^\alpha}\right)^{1/\xi}, \qquad \text{with } \xi > 0 \tag{38}$$

It implies that

$$\frac{p_1'}{p_1} = \left(\frac{h_1'}{h_1}\right)^{-\alpha/\xi}$$

Combine this expression with (36) to get

$$\frac{p_1'}{p_1} = (1-\lambda)^{-\alpha/\xi} > 1 \Rightarrow \text{ real appreciation} \tag{39}$$

Now (37) and (39) imply that

$$\frac{\mathcal{E}_1'}{\mathcal{E}_1} = (1-\lambda)^{1-\alpha+\frac{\alpha}{\xi}} < 1 \Rightarrow \text{ short-run appreciation} \tag{40}$$

We have thus shown that a permanent cut in the money supply causes a nominal appreciation of the domestic currency in the short run. To see whether the exchange rate overshoots, we have to check its the long-run response. That is, we have to see whether in period 2 it appreciates by more or by less than in period 1.

Long Run

The long run is period 2. In the long run, wages are flexible, so there is full employment, $h_2' = h_2 = \bar{h}$.

The cash in advance constraint $M_t = P_t^N C_t^N$, the market clearing condition $C_2^N = F(h_2)$ and the assumption of full employment imply that

$$\frac{P_2^{N\prime}}{P_2^N} = \frac{M_2'}{M_2} = (1 - \lambda) \Rightarrow \text{ long-run core deflation}$$

Finally, (38) and full employment imply that

$$\frac{p_2'}{p_2} = 1 \Rightarrow \text{ relative price unaffected in the long run}$$

Now since $p_2 = P_2^N / \mathcal{E}_2$,

$$\frac{\mathcal{E}_2{}'}{\mathcal{E}_2} = \frac{P_2^{N\prime}}{P_2^N} = (1 - \lambda) \Rightarrow \text{ long-run appreciation} \tag{41}$$

Condition for Overshooting

Comparing (40) and (41) we have that

$$\xi < 1 \Rightarrow \text{overshooting}$$

In words, the TNT-DNWR model predicts exchange rate overshooting if the intratemporal elasticity of substitution between tradables and nontradables is less than one. Available empirical estimates of this elasticity suggest that this is indeed the case.

Overshooting and the Interest Rate

What happens to the nominal interest rate i when the central bank cuts the money supply?

Assume that the condition for overshooting is met ($\xi < 1$), and let's look again at the interest rate parity condition.

$$1 + i = \frac{\mathcal{E}_2}{\mathcal{E}_1}(1 + r^*).$$

Then, after the cut in M_t, the change in i_t is

$$\frac{1 + i'}{1 + i} = \frac{\mathcal{E}_2'/\mathcal{E}_2}{\mathcal{E}_1'/\mathcal{E}_1} = (1 - \lambda)^{\alpha(1-1/\xi)} > 1 \Rightarrow \text{interest rate hike}$$

This says that if the exchange rate overshoots, then a cut in the money supply causes an increase in the nominal interest rate.

Empirical Evidence on Downward Nominal Wage Rigidity

Overview

Downward nominal wage rigidity is the central friction in the TNT-DNWR model.

Is it empirically relevant?

The presence of downward nominal wage rigidity has been documented from different perspectives:

• micro data and macro data

• economies with predominantly formal labor markets and economies with large informal labor markets.

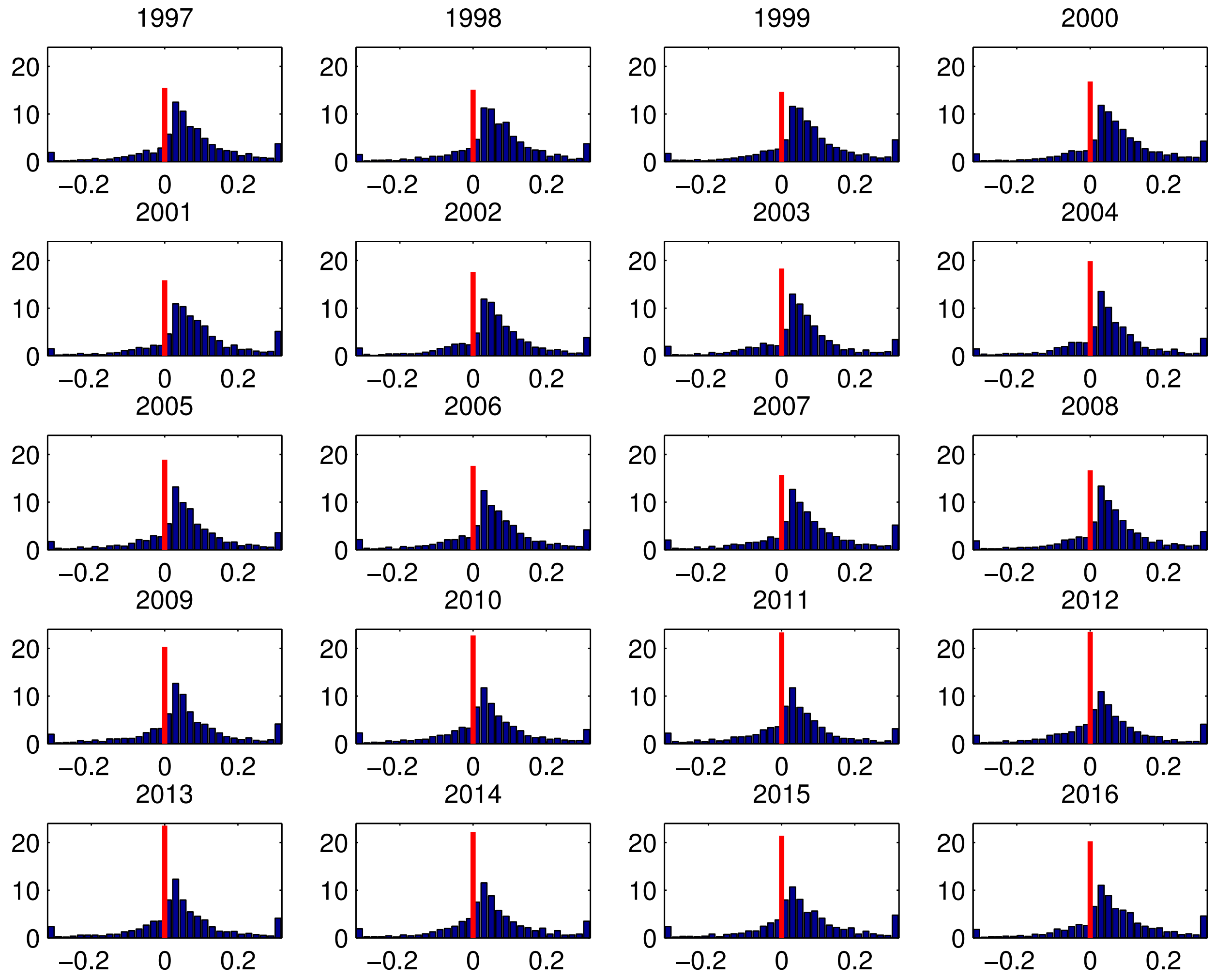
• developed countries, emerging countries

• normal periods and crisis periods

• historical data and recent data

Evidence from U.S. Micro Data

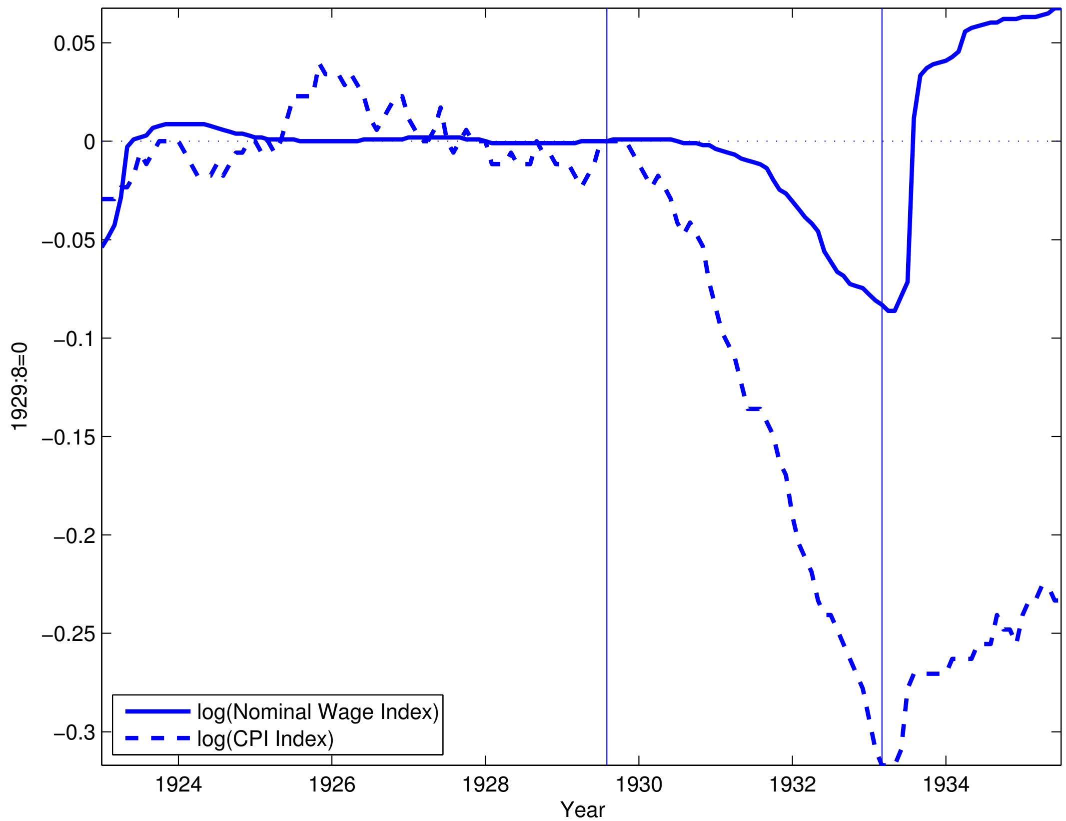
Nominal Wage Change Distributions: US, 1997 to 2016



Comments: The wage change distributions have 3 characteristics consistent with DNWR: (1) a spike at 0; (2) more wage increases than wage cuts; and (3) the spike at 0 increased during the global financial crisis of 2007 to 2009.

Evidence from the Great Depression in the United States

Nominal Wage Rate and Consumer Prices, United States, 1923:1–1935:7



The thick solid line depicts the natural logarithm of an index of manufacturing money wage rates. The broken line depicts the logarithm of the consumer price index. The two vertical lines mark the beginning and end of the Great Depression, August 1929 and March 1933. During the Great Depression nominal wages fell by only 6 percent, whereas nominal prices fell by 32 percent, leading to an increase in the real wage of 26 percent, in spite of a contraction in employment of more than one third of the labor force. Data sources: NBER for the wage rate and BLS for the price index.

Evidence from Peripheral Europe During the Global Financial Crisis

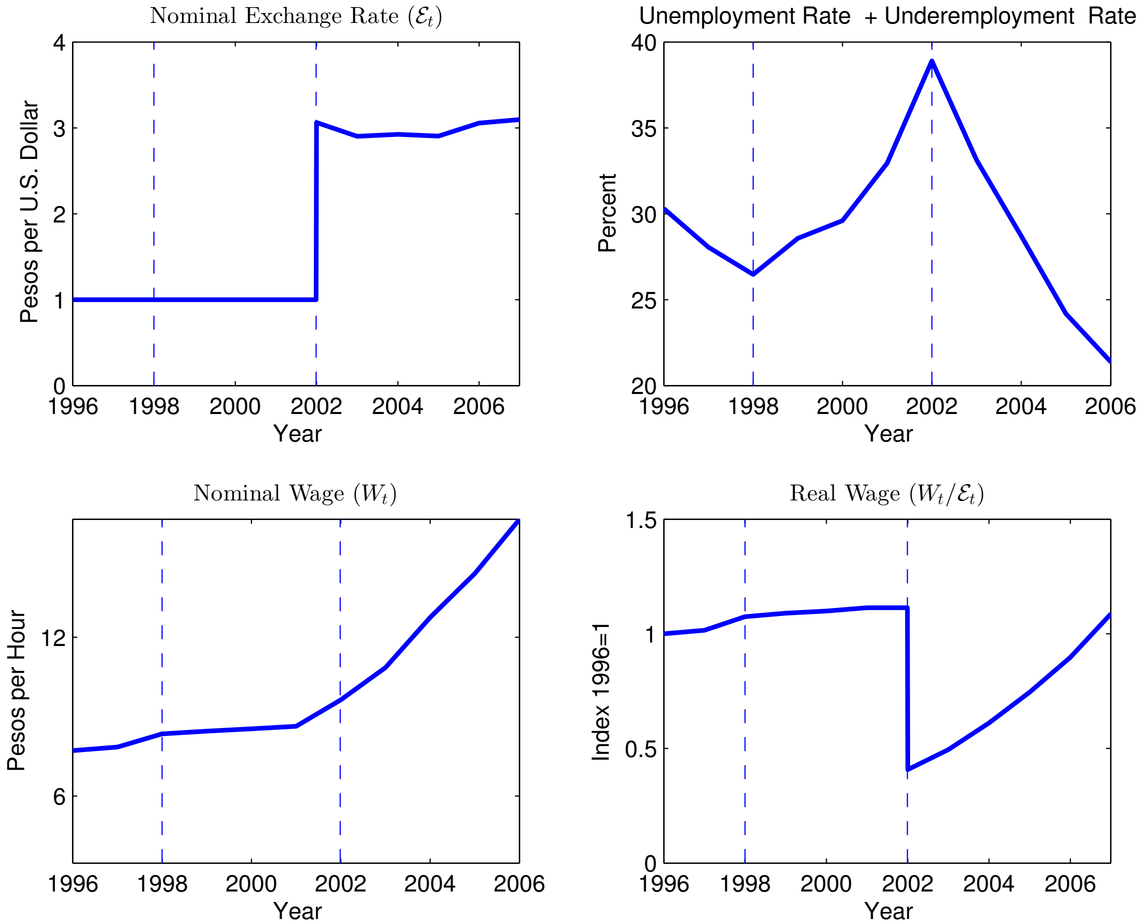
Unemployment and Nominal Wages: Peripheral Europe, 2008–2011

Country	Unemployment Rate 2008Q1 (in percent)	Unemployment Rate 2011Q2 (in percent)	Wage Growth $\frac{W_{2011Q2}}{W_{2008Q1}}$ (in percent)
Bulgaria	6.1	11.3	43.3
Cyprus	3.8	6.9	10.7
Estonia	4.1	12.8	2.5
Greece	7.8	16.7	-2.3
Ireland	4.9	14.3	0.5
Italy	6.4	8.2	10.0
Lithuania	4.1	15.6	-5.1
Latvia	6.1	16.2	-0.6
Portugal	8.3	12.5	1.9
Spain	9.2	20.8	8.0
Slovenia	4.7	7.9	12.5
Slovakia	10.2	13.3	13.4

Comments: All countries were either on the euro or pegging to it. All experienced increases in unemployment. However, none experienced sizable declines in nominal wages in spite of the fact that both productivity growth and inflation were small during this period.

Evidence from the Argentine Peg, 1998–2001

The Last Three Years of the Argentine Convertibility Plan



Evidence of DNWR from Emerging Countries. The large increase in unemployment that characterized the last three years of the Argentine peg occurred in the context of remarkably stable nominal wages, in spite of the fact that the consumer price level (not shown) was falling.

A Numerical Exercise

A Numerical Example: A World Interest Rate Hike

Let's analyze numerically the effects of an increase in the world interest rate, r^*, under a fixed and a floating exchange rate regime.

Assume the following familiar functional forms for preferences and technology:

Preferences: $\ln C_1 + \beta \ln C_2$
Consumption aggregator: $C_t = (C_t^T)^\gamma (C_t^N)^{1-\gamma}$,
Production technology: $F(h_t) = h_t^\alpha$

The table on the next slide presents the assumed values for the parameters, the endowments, and the initial conditions.

Calibration

Parameter	Value	Description
Q_1^T	1	Endowment of tradable goods in period 1
Q_2^T	1	Endowment of tradable goods in period 2
$\bar{h}$	1	Time endowment
B_0	0	Net foreign asset position at beginning of period 1
r^*	0.25	World interest rate
W_0	0.75	Nominal wage in period 0
β	0.8	Subjective discount factor
γ	0.5	Expenditure share of tradable consumption
α	0.75	Labor share in the nontraded sector

Preliminaries: Solving the Equilibrium

Before plunging in the numerical exercise, let's go over how to solve for the complete system of equilibrium conditions, given by expressions (20) to (26) for a given path of the nominal exchange rate $(\mathcal{E}_1, \mathcal{E}_2)$.

(a) Equation (20) gives C_1^T.
(b) C_2^T then comes from equation (21).
Solving for the remaining variables in period 1—period 2 is similar.
(c) Guess that $h_1 = \bar{h}$. $\Rightarrow$ (24) and (26) are satisfied.
(d) (22) then gives p_1.
(e) And (23) gives W_1.
(f) If $W_1 \geq W_0$ then (25) is satisfied and you're done.
(g) If $W_1 < W_0$, set $W_1 = W_0$. $\Rightarrow$ (25) and (26) are satisfied.
(h) Solve (22) and (23) for p_1 and h_1.

You are done.

Numerical Example: The Pre-Shock Equilibrium

Suppose initially the central bank sets

$$\mathcal{E}_1 = \mathcal{E}_2 = 1.$$

We must solve the system of equilibrium conditions (20)-(26).
From (20) and (21)

$$C_1^T = \frac{1}{1+\beta}\left[Q_1^T + \frac{Q_2^T}{1+r^*}\right] = \frac{1}{1+0.8}\left[1 + \frac{1}{1+0.25}\right] = 1$$

$$C_2^T = \beta(1+r^*)C_1^T = 0.8 \times (1+0.25) \times 1 = 1.$$

Guess full employment in both periods: $h_1 = h_2 = \bar{h} = 1$.
Must check that (22)– (26) hold for $t = 1, 2$. Clearly, (24) and (26) are satisfied in both periods.
From (22), $p_t = 1$ for $t = 1, 2$.
Now solve (23) for W_t, $W_t = p_t \mathcal{E}_t F'(h_t) = p_t \mathcal{E}_t \alpha h_t^{\alpha-1} = 0.75$.
$\Rightarrow W_0 = W_1 = W_2 \Rightarrow$ (25) is satisfied.
This completes the proof that the pre-shock equilibrium features full employment in both periods.

Numerical Example: Adjustment with a Fixed Exchange Rate

Suppose that r^* increases to 50% ($r^{*\prime} = 0.5$) and that the central bank fixes the exchange rate at 1 ($\mathcal{E}_1 = \mathcal{E}_2 = 1$).

Again, we must solve the system of equilibrium conditions (20)-(26).

By (20) and (21), $C_1^T = 0.9259$ and $C_2^T = 1.1111$.

Guess that the wage constraint is binding: $W_1 = W_0 = 0.75$.

Obviously (25) and (26) hold.

Combining (22) and (23) to eliminate p_1 yields $h_1 = 0.9259 \Rightarrow$ unemployment.

Since $h_1 < 1$, (24) is satisfied.

From (22) $p_1 = 0.9809 \Rightarrow$ real depreciation.

Period 2:

Guess full employment in period 2, $h_2 = \bar{h} = 1$.

Trivially(24) and (26) hold.

From (22), $p_2 = 1.1111$.

Solve (23) to get $W_2 = 0.8333$.

Since $W_2 > W_1$, (25) is satisfied in period 2.

Numerical Exercise: Summary of Adjustment to an Increase in r^* with a Fixed Exchange Rate

Period 1:

- Consumption of tradables and nontradables falls.
- Involuntary unemployment emerges.
- The real exchange rate depreciates.
- The trade balance, the current account, and the country's net asset position improve.
- There is deflation in core prices.

Period 2:

- Consumption of tradables and nontradables increases.
- Full employment is restored
- The nominal and real wage increases.
- The real exchange rate appreciates.
- There is core inflation.

The table on the next slide presents a numerical summary of these effects.

Summary of Effects of an r^* Hike in the TNT-DNWR Model

	Pre Shock	Fixed	Floating
r^*	0.25	0.5	0.5
$\mathcal{E}_1$	1	1	1.0800
$\mathcal{E}_2$	1	1	0.9000
h_1	1	0.9259	1
h_2	1	1	1
$W_1/\mathcal{E}_1$	0.75	0.75	0.6944
$W_2/\mathcal{E}_2$	0.75	0.8333	0.8333
W_1	0.75	0.75	0.75
W_2	0.75	0.8333	0.75
p_1	1	0.9809	0.9259
p_2	1	1.1111	1.1111
P_1^N	1	0.9809	1
P_2^N	1	1.1111	1
C_1^T	1	0.9259	0.9259
C_2^T	1	1.1111	1.1111
TB_1	0	0.0741	0.0741
TB_2	0	-0.1111	-0.1111
CA_1	0	0.0741	0.0741
CA_2	0	-0.0741	-0.0741
B_1	0	0.0741	0.0741

Note. The calibration of the TNT-DNWR model used in this example is shown in slide 66.

Numerical Exercise: Adjustment with a Floating Exchange Rate

We know that in response to an r^* shock, a floating exchange rate can maintain price stability and full employment.

So let's verify that eq'm conditions (20)-(26) are satisfied. with $P_t^N = 1$ and $h_t = \bar{h} = 1$, for $t = 1, 2$.

The path of consumption of tradables is independent of monetary policy, so $C_1^T = 0.9259$ and $C_2^T = 1.1111$.

Clearly, (24) and (26) hold for $t = 1, 2$.

From (22), $p_1 = 0.9259$ and $p_2 = 1.1111$, and therefore $\mathcal{E}_1 = 1.0800$ and $\mathcal{E}_2 = 0.9000$.

From (23), $P_t^N = W_t/(\alpha \bar{h}^{\alpha-1})$, so $W_t = \alpha = W_0$ for $t = 1, 2$ and (25) is satisfied for $t = 1, 2$.

The last column of the table in slide 71 summarizes these results.

The Welfare Cost of a Currency Peg

Let C_t^p, C_t^f denote consumption under a peg and a float. Then, from (7), $C_1^p = 0.9349$, $C_1^f = 0.9623$, and $C_2^p = C_2^f = 1.0541$.

From (6), lifetime utility is -0.0252 and 0.0037 utils for the peg and the float.

Definition. welfare cost of a currency peg = percent increase in consumption in each period (λ) that a household in a currency peg requires to be as happy as a household in a float. Formally,

$$\ln\left[(1+\lambda)C_1^p\right] + \beta \ln\left[(1+\lambda)C_2^p\right] = \ln C_1^f + \beta \ln C_2^f.$$

Let U^p, U^f = utility under a peg and a float. Then, solving for λ,

$$\ln(1+\lambda) = \frac{U^f - U^p}{1+\beta} = \frac{0.0037+0.0252}{1+0.8} = 0.016$$

Using $\ln(1+\lambda) \approx \lambda$, $\lambda = 0.016$.

So households in a peg require a 1.6 percent increase in consumption each period to be as well off as in a float.

Summing Up

This chapter shows that in the presence of nominal rigidity, monetary and exchange rate policy can affect the equilibrium levels of inflation, unemployment, aggregate activity, and the real exchange rate. It considers separately two exchange rate regimes: a fixed exchange rate regime and a floating exchange rate regime in which the central bank pursues the dual mandate of full employment and price stability.

- We embedded downward nominal wage rigidity into the TNT model to get the TNT-DNWR model.
- In the TNT-DNWR model, the nominal wage can go up but not down.
- Under a fixed exchange rate regime, negative external shocks, such as an increase in the world interest rate or a deterioration of the terms of trade, cause involuntary unemployment.
- Under a floating exchange rate regime, in response to negative external shocks the central bank can preserve full employment and price stability by depreciating the domestic currency.
- When the economy is buffeted by external shocks, welfare is higher under a floating exchange rate than under a currency peg.

Summing Up (concluded)

• In response to negative supply shocks, such as a fall in productivity in the nontraded sector, the monetary authority faces a trade-off between inflation and unemployment, so stagflation may occur.

• The monetary policy trilemma says that the monetary authority can achieve only two of the following: (1) a fixed exchange rate; (2) setting the nominal interest rate independently; and (3) free capital mobility.

• Under a flexible exchange rate regime, a monetary tightening can cause exchange rate overshooting, that is, a larger appreciation in the short run than in the long run.

• There is empirical evidence consistent with the presence of downward nominal wage rigidity in data from developed and emerging countries.