Intermediate Macroeconomics

DSGE Models: The Frontier of Business Cycle Research

ECON 3311 – Fall 2024

UT Dallas

Overview

Dynamic → Consider how vary over time & how current decisions depend on Past and Future economic variables

Stochastic → Accounts for uncertainty on future economic variables and shocks.

General Equilibrium → Now we solve jointly for all Variables in the economy

In this lecture:

- Introduction to **Business cycle models** and growth models and their connection with the frontier of macroeconomics.
- **DSGE:** Dynamic Stochastic General Equilibrium models.
    - Framework incorporating **shocks, expectations, and microfoundations**
- Model yielding quantitative predictions about the dynamics and evolution of an economy in response to shocks

Microfoundations: emphasis on consistency between macroeconomic outcomes & microeconomic behavior.

Introduction

Revolution in Macroeconomic Modeling

Developed in 1970s-1980s and used to this day

Innovation: Introduction of microeconomic foundations for macro models

More rigorous than (previous) approaches based only on statistical observation (Correlation -vs- Causation) (Mechanisms)

DSGE Models:

DSGE = Dynamic, Stochastic, General Equilibrium.

Dynamic: Analysis of evolution of the macroeconomy over time

Stochastic: Incorporates economic shocks

General Equilibrium: Endogenously determines every price and quantity in the economy

This lecture

- Historical development of DSGE models.
- Stylized version focusing on the labor market.
- Description of a Quantitative Theory: Estimated model used for making predictions about the economy's response shocks

A Brief History of DSGE Models

Up to 1970's: Little recognition of shocks; only account of (+)/(−) expected relationship between variables.

1980's: RBC → Study economic cycles driven by shocks.

Introduction of Real Business Cycle (RBC) Models

First DSGE models: known as Real Business Cycle models

Based on the Solow growth model RBC: Solow + TFP shocks (In General Equilibrium)

Incorporation of TFP Shocks

Modification: Introduction of Total Factor Productivity (TFP) shock

TFP is not constant but fluctuates over time

Shocks drive fluctuations and lead to cycles: booms & recessions

Significance of TFP Shocks

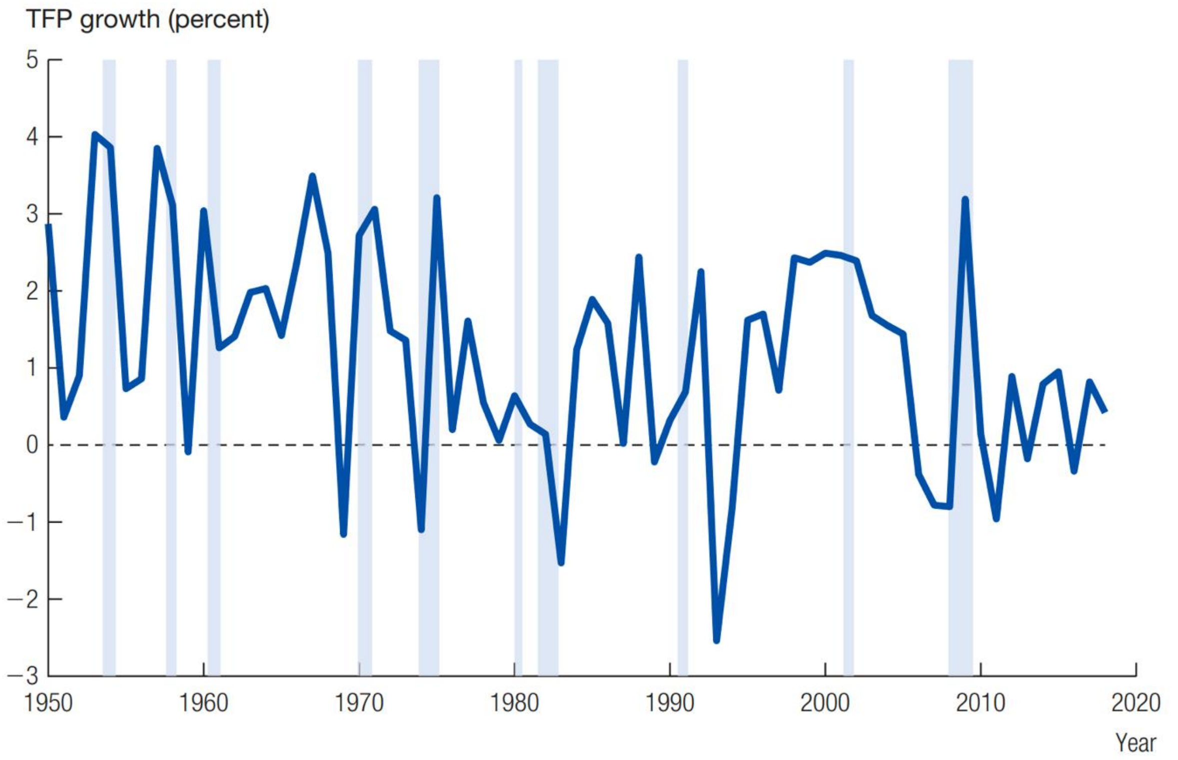
Positive TFP shock: Higher (than normal) economic growth

Example: Technological improvement

Negative TFP shocks: may result in GDP decline

RBC: Economy dynamics driven by real shocks

U.S. Total Factor Productivity Growth



Source: John Fernald, "A Quarterly, Utilization-Adjusted Series on Total Factor Productivity," Federal Reserve Bank of San Francisco, www.frbsf.org/economic-research/indicators-data/total-factor-productivity-tfp/.

Limitations of TFP Shocks as sole drivers

Limitations: There are other shocks (e.g., Demand, Financial, etc)

Critical Analysis of TFP Shocks

- Some recessions, like in 2001, show no significant negative TFP shock.
- What about the 2009 financial crisis with no evident positive TFP shock?

⇒ RBC Is still insufficient

But it still provided key methodological innovations:

- Microfoundations
- General Equilibrium
- Introduction of Expectations in models
- Dynamics: $y_{t-1}, y_t, E_t[y_{t+1}]$

Main value added of RBC models: The methodology

- Use of empirically robust models with solid microeconomic foundations.
- However, RBC models have limitations in explaining all economic fluctuations.
  - In a nutshell: There are more shocks out there

But the idea is so powerful that led to the **synthesis** of schools of thought in macro:

Neoclassical macro + Keynesians: **New-Keynesians**

⇒ From RBC: Take methods → add more shocks & $\underbrace{\text{Potential market failures}}_{\text{From Keynesians}}$

⇒ Get New Keynesian – DSGE

From Real Business Cycles to DSGE

Prior to RBC: → Mostly "correlational" studies (e.g. Initial Phillips Curve)

Economic "models" based on statistical correlations: not always consistent with economic behavior, confused correlation with causation

Problem: Only capture +/− relationships but ignore other features } e.g. Stagflation of 1970's (↑π, ↑u)

Evolution from RBC to DSGE:

Early models based on Solow by (Kydland, Prescott, Long, and Plosser) led to enriched macro modeling

- Prescott's prediction: Models are abstract and statistically rejected, but valuable insights are gained
- TFP shocks are real and create cyclical output fluctuations —hence the name (RBC)
- Further research introduced public finance, foreign sectors, and monetary factors

Shift to DSGE Models:

- RBC models seen as a rather special case within a larger framework (DSGE)
- New setups allow for market failures and inefficiencies as those observed in reality

example: Sticky Prices (inflation)

Key Components of DSGE Models

Endogenous Variables:

Central economic variables like GDP, consumption, investment, employment, and inflation.

Labor market: employment decisions affect overall output.

Shocks:

As previously, output is at its potential and departs from it after a shock — the difference between actual and potential is a cyclical fluctuation

Economic **fluctuations due to shocks**: TFP, policies, taxes, monetary policy, and more

Shocks can be temporary or permanent, immediate or anticipated.

Uncertainty about future events can impact economic decisions and activity.

Key Features of DSGE Models

allow for market failures that prevent them to work as expected (efficiently)

Nominal Rigidities:

- DSGE: includes features like nominal rigidities and other market frictions
- Sticky wages/prices: examples of frictions allowing monetary policy to have real economic effects

Adjustment Costs:

- Too simplistic DSGE models imply a much quicker reaction to shocks than seen in reality
- To deal with this: include features that enhance the smooth behavior of the economic variables
- Adjustment Costs: “extra” costs of changing the stock of capital (can be substantial)

menu costs, Investment costs, transaction cost

Heterogeneity:

- Modern DSGE models incorporate heterogeneity among agents (e.g., differences in labor supply)

Incomplete Markets:

- Earlier models assumed complete markets, where all risks could be traded and insured.
- Recent models recognize that reality features frictions that prevent markets from working perfectly and include from market - efficient outcomes

lower capacity of people of insuring risk or smoothing consumption

The inclusion of all these new features improve the model’s capacity to explain (fit) the economic data.

Mathematics and Complexity in DSGE Models

Objective: account for the dynamic behavior of variables. Implies including their **future values** and incorporating their **uncertainty**. These modifications imply a more complex mathematical setup:

Decision-Making Over Time—microfoundations:

Key difference between DSGEs and earlier models: Inclusion of **individual optimal** decision-making over time.

Individuals make choices each period that affect future periods: savings, consumption, labor, etc.

Model Complexity:

Complexity arises from the need to solve for decisions over many periods (e.g., 200 quarters over 50 years).

While accounting for what occurs in the future given the current shocks and decisions

- Implies taking expectations seriously: can be a daunting task (e.g., computationally)

These features were simply overlooked in previous models but can make a big difference

Approaches to Understanding DSGE Models: several, here we cover two common approaches:

Study a particular component with rigor while simplifying the other features: For example, the Labor Market.

Numerical solutions of more advanced DSGE models. Solve for the whole economy dynamics at the same time.

Normally a researcher has to do both to understand the whole picture.

A Stylized Approach to DSGE

DSGE models typically include several markets: labor, capital, assets, output (final goods), etc.

Many markets clearing simultaneously is what makes it **General Equilibrium** setup

To simplify, let's focus for now on a single of these markets: The labor market

Supply and Demand surpluses clear given some prices

Labor Demand: The labor demand curve reflects firms' profit-maximizing decisions (microfoundations).

- Firms hire additional labor until the marginal product of labor equals the real wage.
- The marginal product of labor decreases as more labor is hired.

Key Equations:

•The basic production function: $Y = \bar{A}K^{1/3}L^{2/3}$

•Labor demand function: $w = \frac{2}{3} \cdot \frac{\bar{A}K^{1/3}}{L^{1/3}}$

Comes from Profit maximization

•This result (coming from the microeconomic decisions) already accounts for the negative relationship between real wage (w) and employment (L).

A Stylized Approach (continued)

The Labor Market:

Demand: Slopes downward (with higher wages firms search for fewer workers)

Notice we take this from the optimality condition of firms

Supply: Slopes upwards

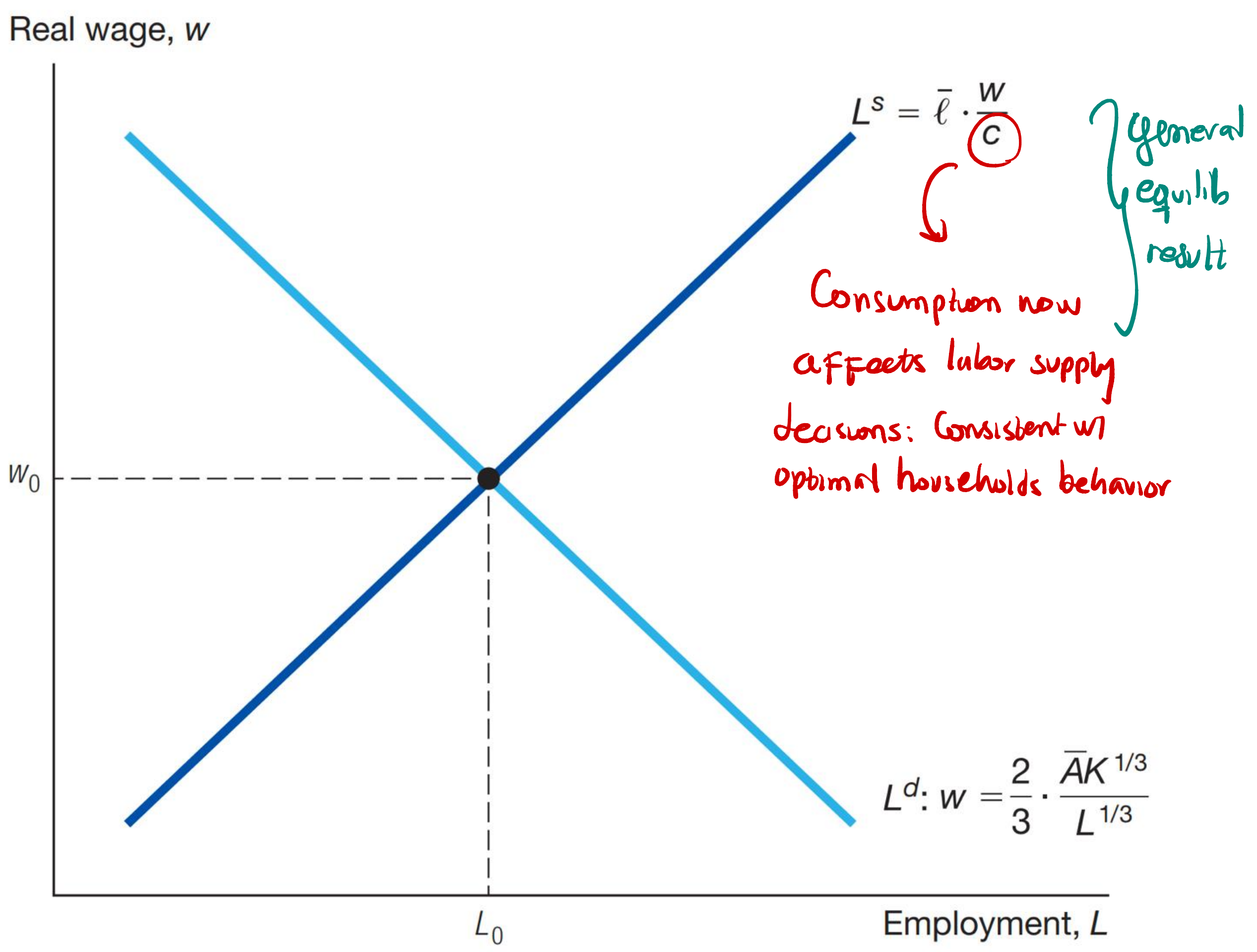
Notice consumption is in the supply equation…why? Because when deciding how much to work people trade off income (and consumption) with leisure

> [this is the type of microfoundations that previous approaches fail to account for but that can matter]

Impact of positive TFP shocks: Shift labor demand curve

Shock is a factor of the MPL: Increasing "effective" MPL
→ Makes firms willing to hire more!

The Labor Market in the DSGE Model



Understanding Labor Supply in DSGE Models

Labor Supply Curve:

- Reflects individuals' decisions on how much to work based on maximizing their utility.
- Decision factors include the trade-off between income and leisure time.

$$L^s = \bar{\ell} \cdot \frac{w}{c}$$

L^s: labor supply, *w*: real wage, *c*: consumption per person.

Labor Demand:

$$w = \frac{2}{3} \cdot \frac{\bar{A}K^{1/3}}{L^{1/3}}$$

Identical to the one we saw in the Production function and Solow model lecture

Equilibrium: L that equates Supply & Demand.

Actual labor observed: The **equilibrium Labor** is the *L* equating both equations.

Equilibrium in the Labor Market

Equilibrium in the Labor Market:

- labor supply equals labor demand, determining the real wage and the amount of labor used in production
- Represented in the graph by points w_0 and L_0.

Simplification in DSGE Models:

- In this simplified analysys we are not formally modeling consumption across time.
- Full DSGE models include intertemporal setups where consumption, savings, and labor supply decisions maximize lifetime utility.

Using the model: A Negative TFP Shock

Case: ↓TFP: $w=\frac{2}{3}\left(\frac{K}{L}\right)^{1/3} A\downarrow$

A negative TFP shock reduces productivity, leading to lower production output.

$\downarrow MPL \rightarrow \downarrow L^{demand}$

$\rightarrow \downarrow$ Wages

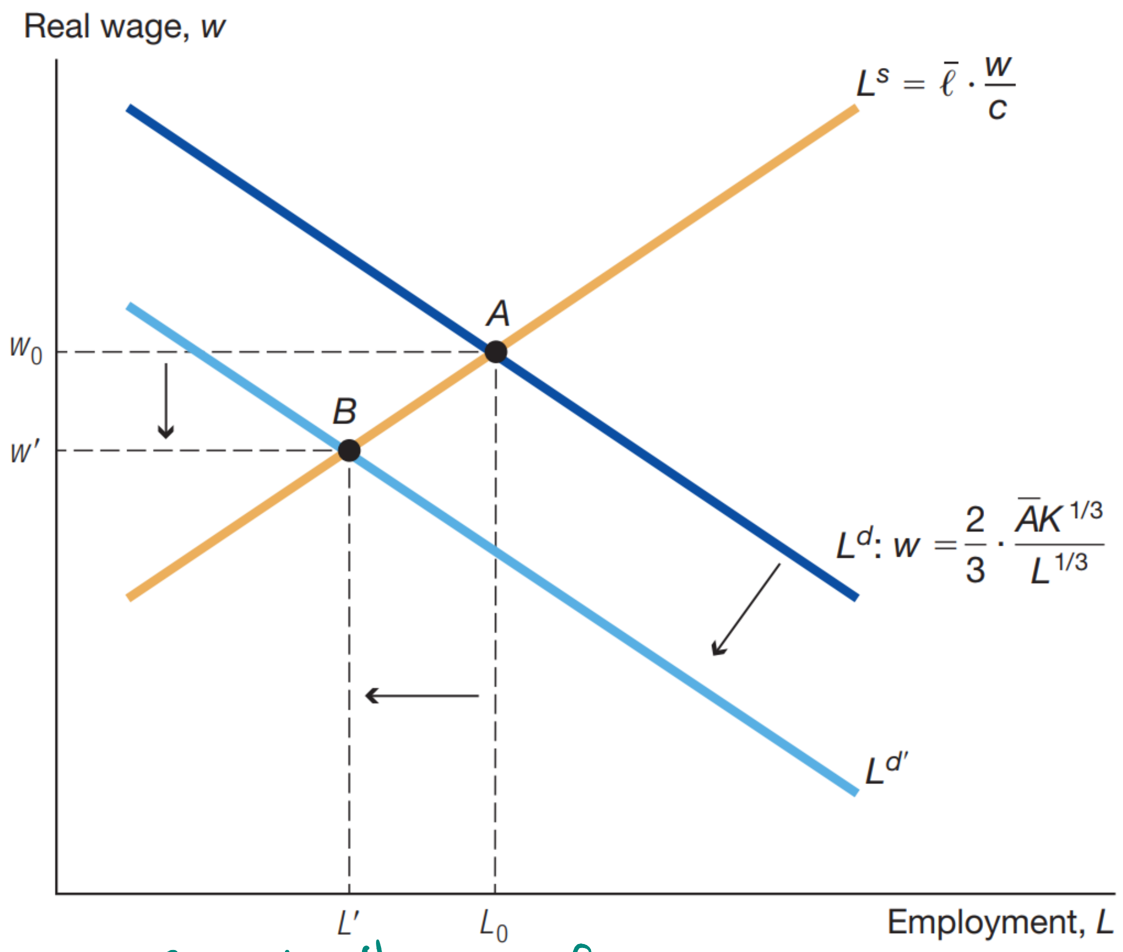
Impact on Labor Market:

- MPL lowers which shifts the labor demand to the left: lower employment and reduced real wages.
- labor supply: unchanged as it is not affected by TFP

Equilibrium Shift:

- The labor market equilibrium moves A to B,
- Indicating a recession-like scenario with lower employment (L ′)and wages (w ′)

A Negative TFP Shock in the DSGE Model



Note: The analysis here is similar than in short-run model diagram ... But now key equations come in all cases from equations consistent with optimal microeconomic behavior (Called in studies: First Order Optimality necessary conditions.)

A Rise in Taxes Paid by Firms

Case 2: ↑ Taxes (for firms)

$\downarrow w = (1-\overset{\uparrow}{\tau}) \frac{2}{3}\left(\frac{K}{L}\right)^{1/3} A$

Introduction:

Rise in taxes on firms: Affects labor market similarly to a negative TFP shock.

This example: temporary increase in tax rate on labor demand

Effect on Labor Demand:

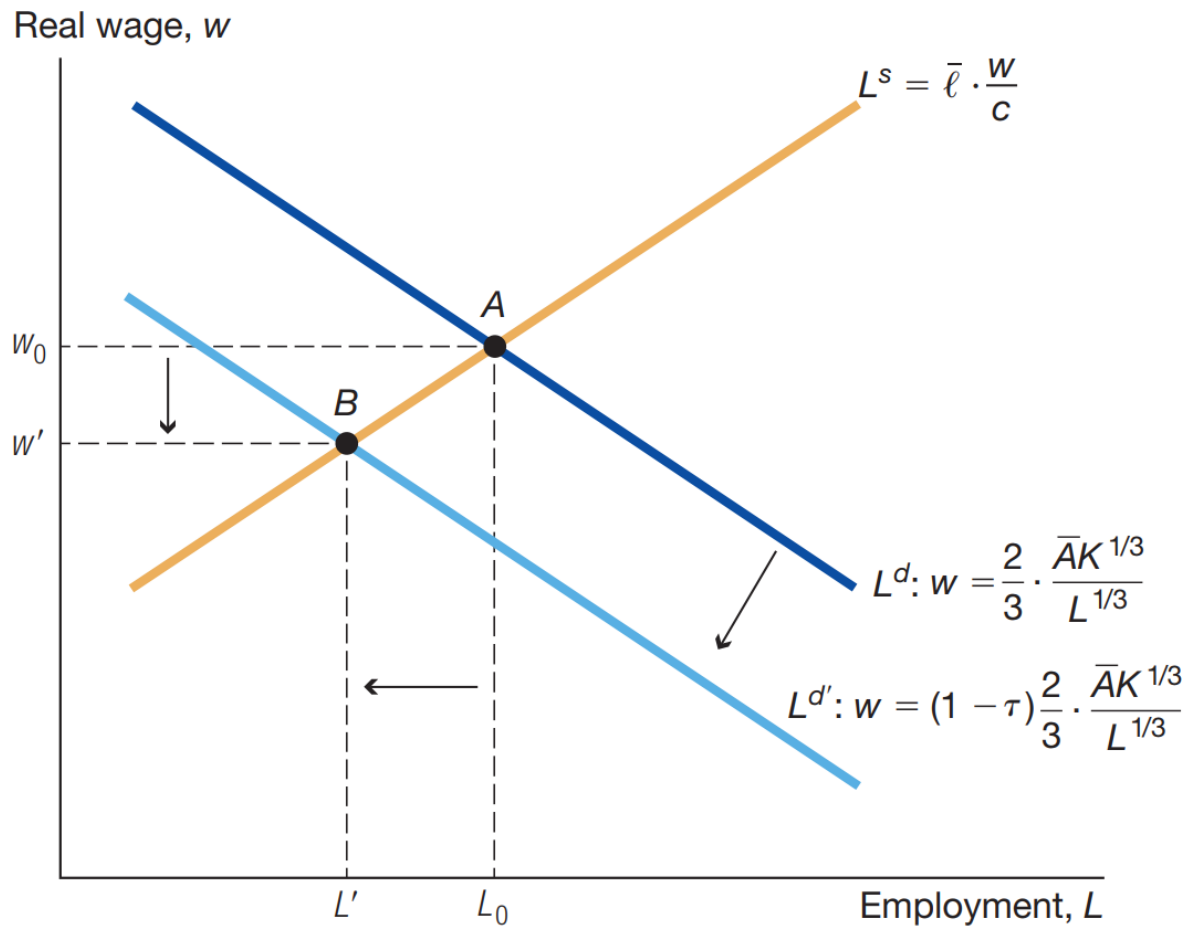
When firms face higher taxes, the **after-tax marginal product of labor decreases**, causing the labor demand curve to shift.

New labor demand equation after the tax increase:

$$w = (1-\tau)\frac{2}{3}\cdot\frac{\bar{A}K^{1/3}}{L^{1/3}}$$

The shift leads to lower equilibrium wages and employment

The Imposition of a Sales Tax in the DSGE Model



A Permanent Rise in Government Purchases ↑ Gov. Spending

(at first) Nothing seems to happen... But Consumption lower as people anticipate ↑ Taxes

Impact on Consumption:

Government spending does not directly affect the labor supply or demand curves

But it impacts consumption: The anticipated rise in taxes reduces permanent income, lowering consumption

Effect on Labor Supply:

To compensate, people work more (reduce leisure), increasing labor supply

Labor supply curve shifts to the right

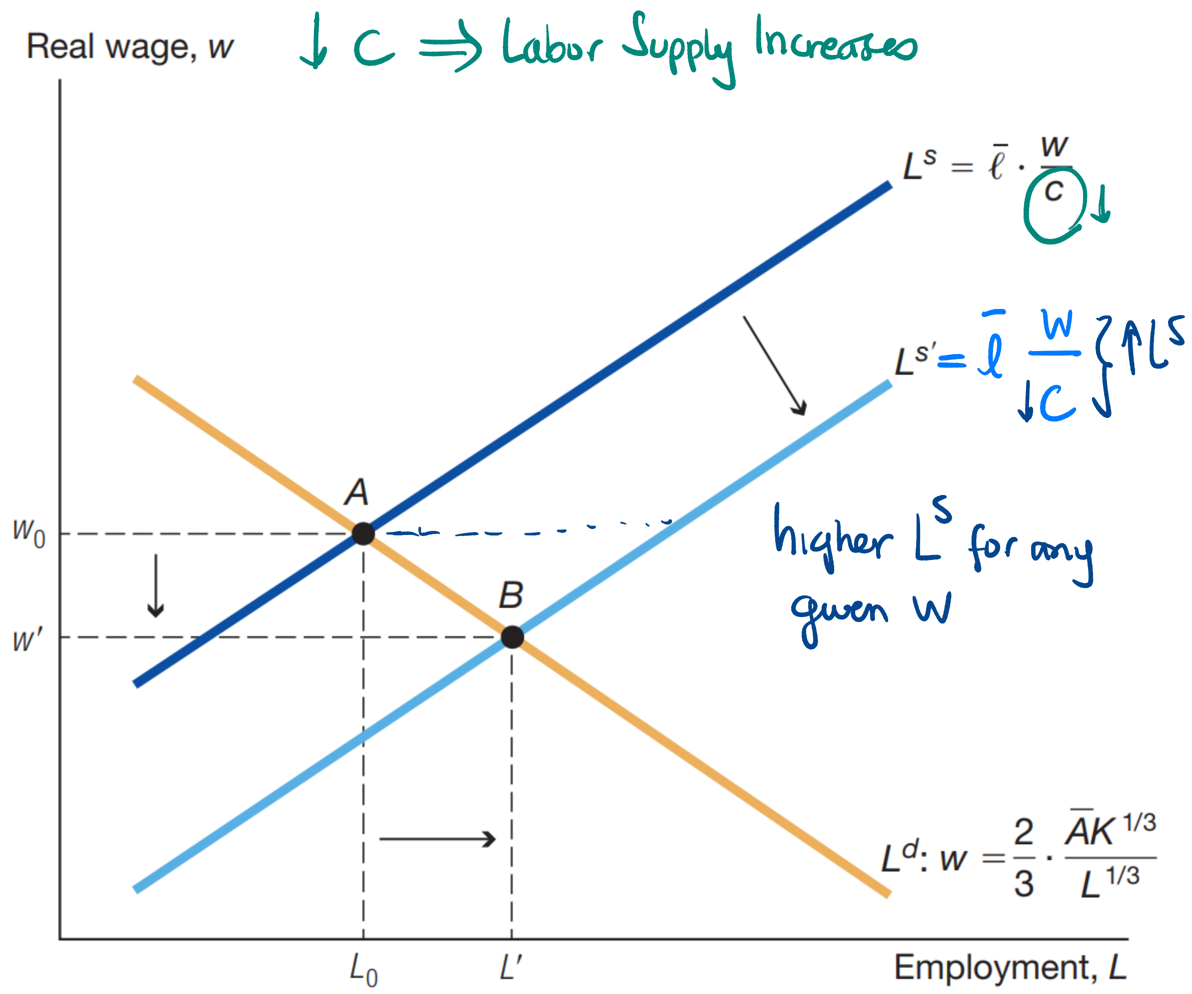
Equilibrium Shift:

The equilibrium in the labor market moves from A to B.

Employment increases but real wages decrease

Capturing this effect is possible only because we are accounting for optimal microeconomic behavior

A Rise in Government Purchases



Monetary Policy & Unemployment: Sticky Wages

Introduction to Sticky Wages:

Sticky wages: nominal wages don't adjust quickly to changing economic conditions

We rarely see downward adjustments

This can lead to unemployment when wages are stuck above the market-clearing level

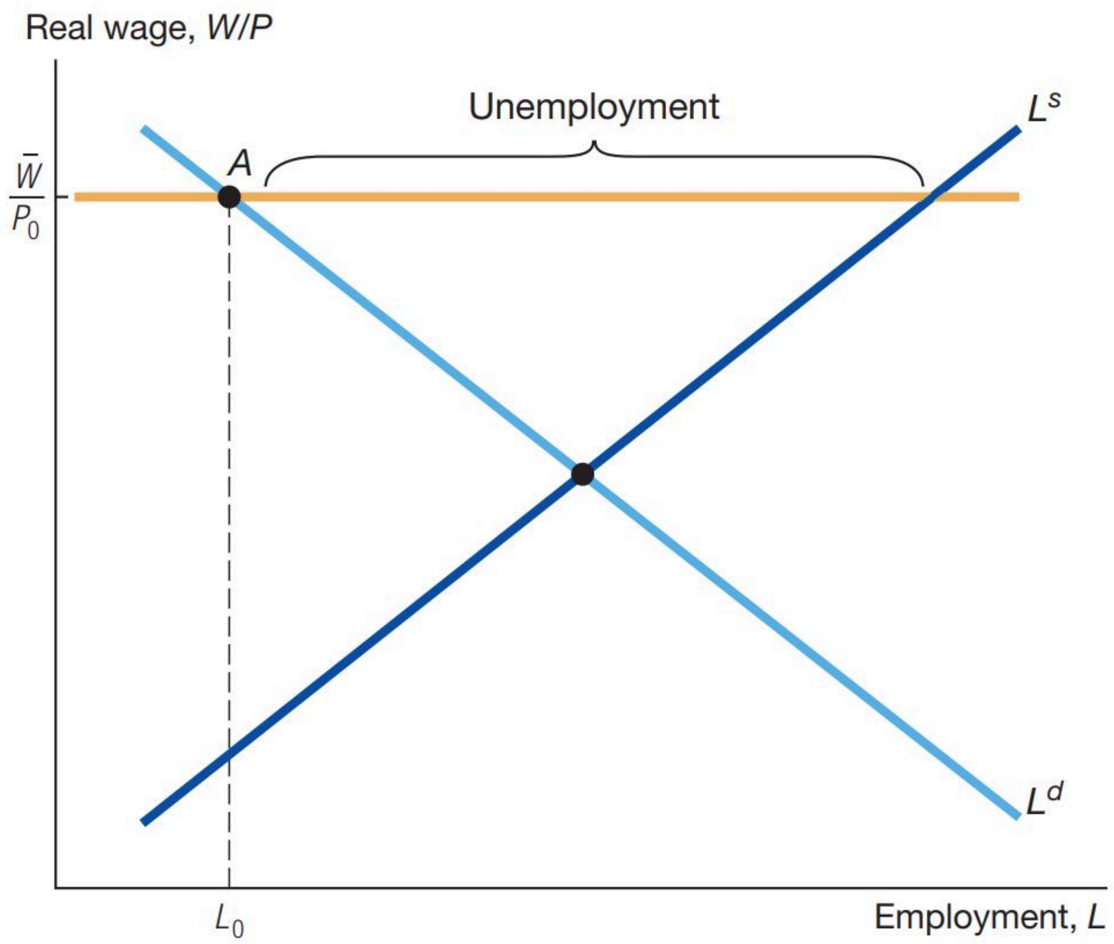
Labor Market with Sticky Wages:

When nominal wages are fixed at $W = \bar{W}$, and prices adjust, the real wage changes.

Labor demand curve L^d intersects the labor supply curve L^s at a point where the wage does not clear the market

Leading to involuntary unemployment.

Sticky Wages in the DSGE Model



Monetary Expansion with Sticky Wages

Monetary Policy Expansion:

Interest rates lower and prices rise: **real wage lowers** to $\frac{\bar{w}}{P'}$ when nominal wages are sticky

Leading to a higher labor demand and lower labor supply

Employment increases

Impact on Employment and Wages:

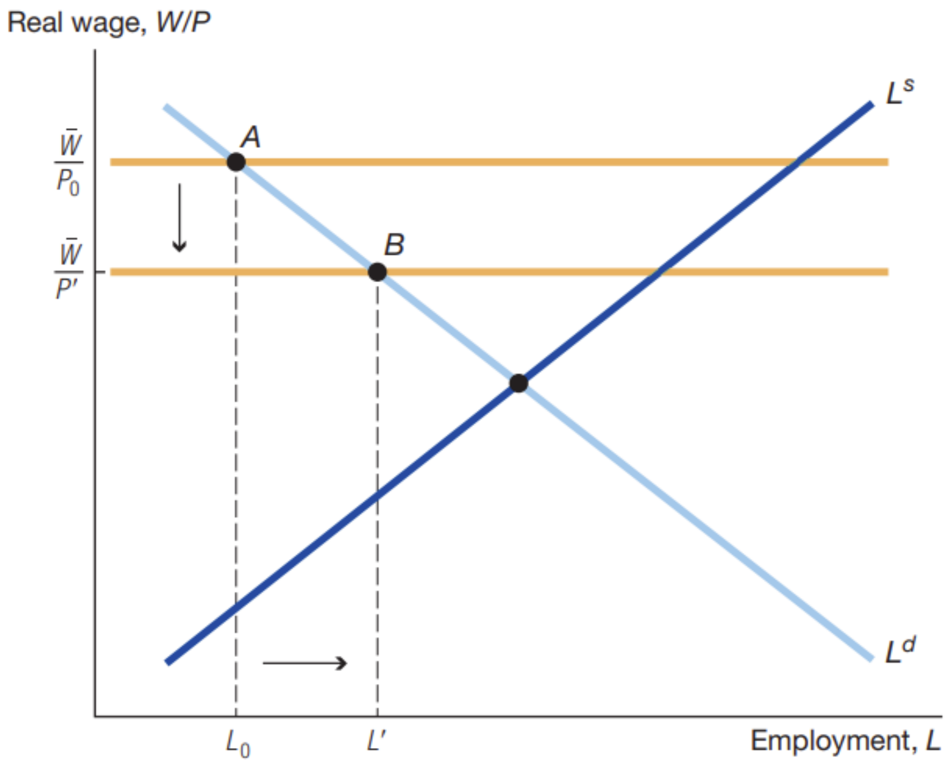
Economy goes from A to B

Employment increases from L_0 to $L^{'}$

However, real wages decrease: counterintuitive to what is expected during economic booms

We can also consider sticky prices

A Monetary Expansion with Sticky Wages



Monetary Policy and Sticky Prices

Sticky prices: prices of goods and services adjust slowly in response to changes in the economy.

Supply usually grows with prices but as the latter are fixed, we assume firms produce quantities dictated by the demand

Thus, demand for labor is the same regardless of wages

Labor Market with Sticky Prices:

Labor demand curve becomes vertical

Labor supply curve shifts to the right due to monetary policy's positive effect on aggregate demand and output

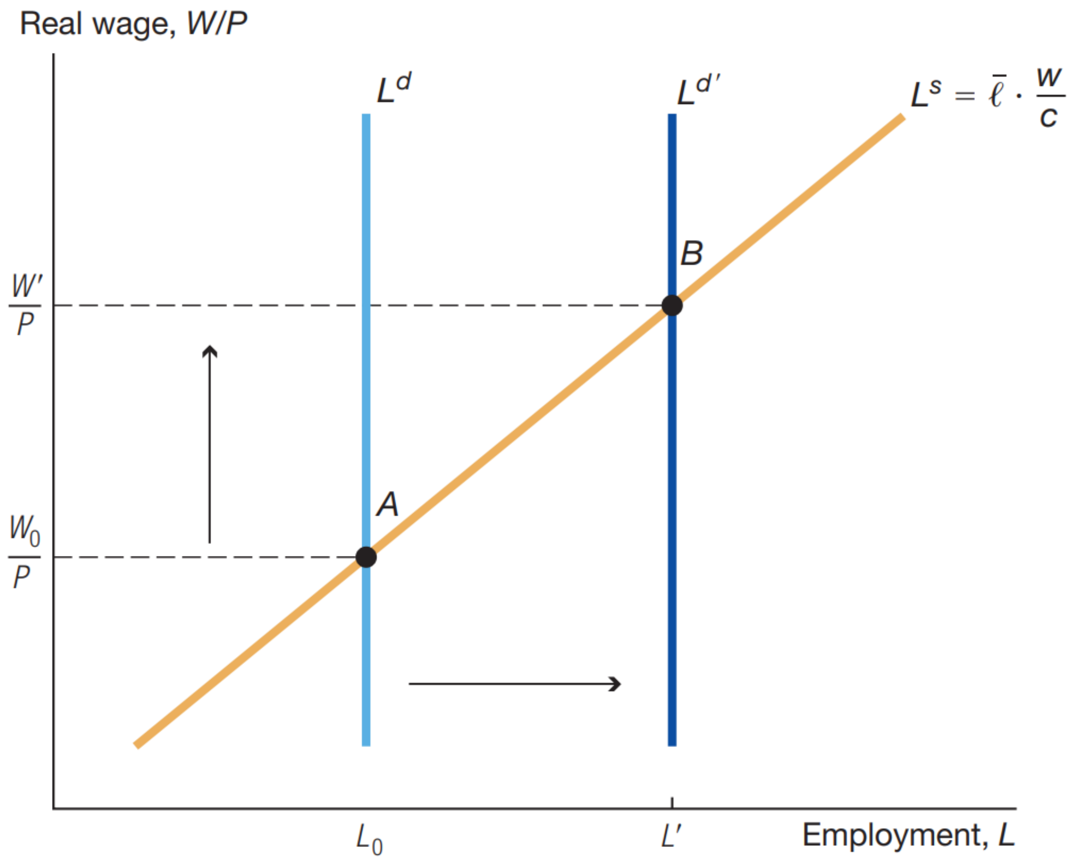
Impact on Employment and Wages:

Employment increases from L_0 to $L^{'}$, wages rise from $\frac{w_0}{P}$ to $\frac{w'}{P}$

Higher real wages aligns with the business cycle behavior where employment and wages move in the same direction

In reality, we can see a combination of both sticky wages and sticky prices happening simultaneously

A Monetary Expansion with Sticky Prices



Quantitative DSGE Models

Richer models than the comparative static plots from before

Account for the complete dynamic response of all economic variables to a shock

- Thus, it captures —general equilibrium— effects not apparent in the diagrams we have used so far

Beyond "this goes up, this goes down"

With this, we don't only know whether a variable increases/lowers but also: By how much, for how long, how quickly, etc.

Much more appropriate laboratory for comparing policies!

- Example: Fed can compare economic effects of increasing rates by 25bp, 50bp, or 25bp today and 25bp later.

Furthermore: the parameters of the models are often estimated or adjusted to fit better the (economy) data of interest

This type of setup is what institutions use currently: Fed, Bank of Canada, Bank of England, IMF, ECB, etc.

Here we show one of the new possible analyses through a tool called "Impulse Responses" … but know that many more become available with these models!

Impulse Response Functions

Impulse Response Function (IRF): shows how a variable (like GDP) responds over time to an economic shock

Example: Monetary tightening (FFR increase)

A 1% increase in the fed funds rate leads to an initial 0.2% decline in GDP.

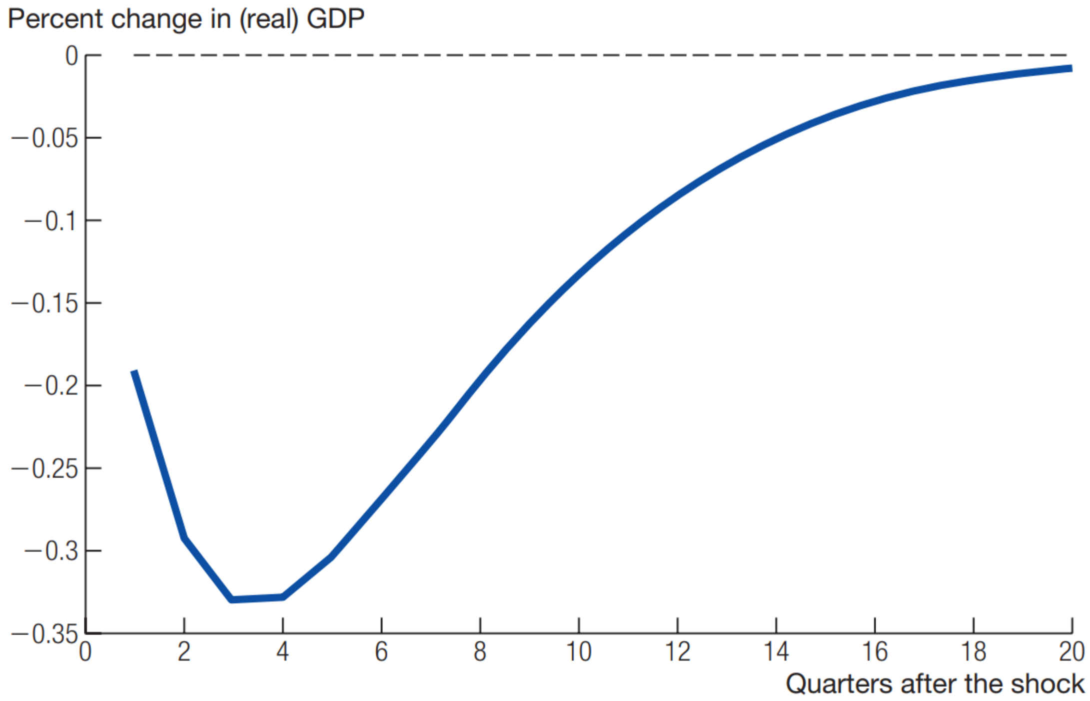
The maximum effect on GDP occurs 3-4 quarters after the shock, with a 0.33% decline.

Over several years, GDP gradually returns to normal, showing the dissipation of the shock.

Note things we can capture here that would be impossible in the diagrams we saw before:

- Delayed increase in response (hump-shaped)
- Size of effect
- Feedback effect of this variable into the rest (general equilibrium)

The Response of GDP to a Monetary Policy Shock



Source: Frank Smets and Rafael Wouters, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review,* vol. 97, no. 3 (2007), pp. 586–606.

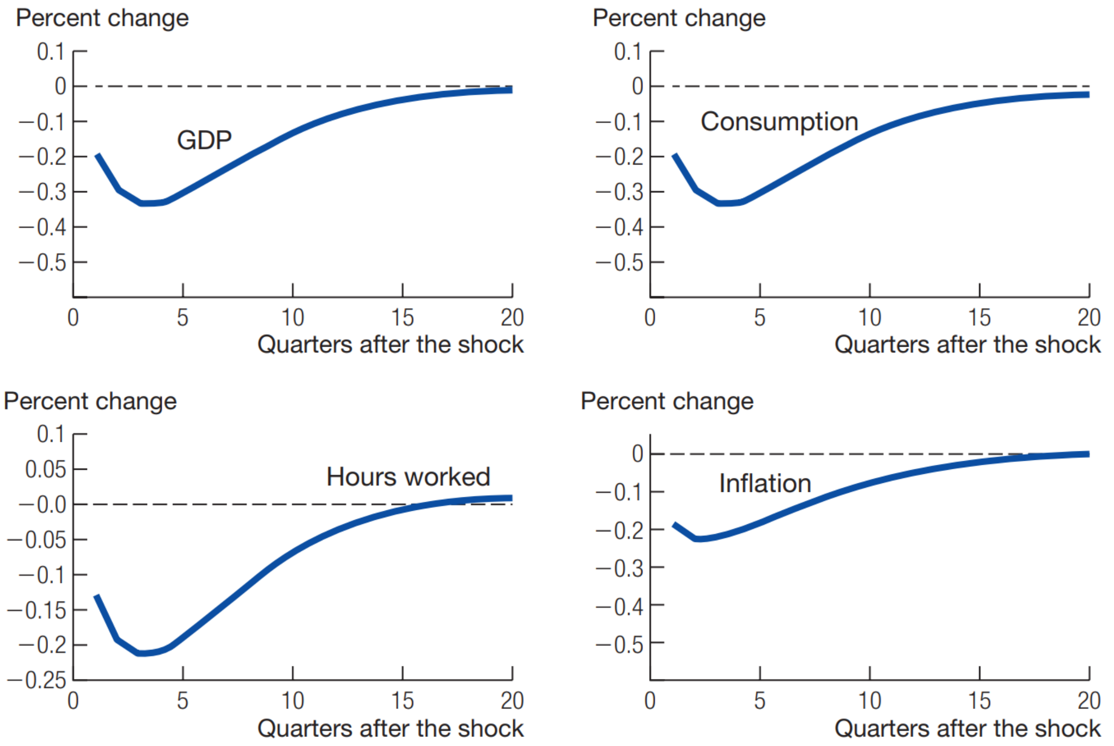
Dynamic Effects of a Monetary Policy Shock

Affected Variables: GDP, consumption, hours worked, and inflation are all impacted by a monetary policy shock.

Magnitude and Timing:

- **GDP**: Initial decline, reaching maximum impact after about a year, and slowly returning to normal
- **Consumption**: Similar pattern to GDP, but slightly smaller in magnitude
- **Hours Worked**: Decline due to reduced labor demand
- **Inflation**: Gradual decline, reflecting reduced demand and economic activity

The Dynamic Effects of a Monetary Policy Shock



Source: Frank Smets and Rafael Wouters, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol. 97, no. 3 (2007), pp. 586–606.

Notice this setup also captures how shocks dissipate and eventually go back to their long-run values (we called this before "transition dynamics")

Total Factor Productivity Shock

TFP shock: sudden 1% increase in the overall productivity

In the Smets and Wouters model, a typical TFP shock is temporary but has long-lasting effects, slowly decaying over several years.

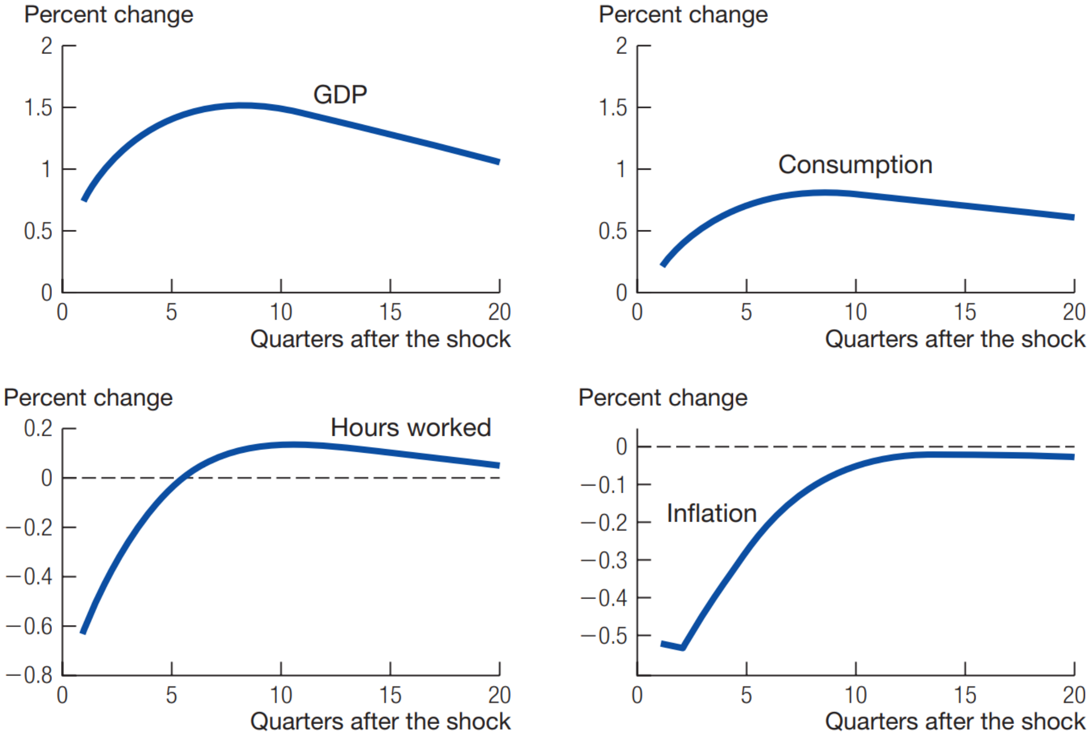
The effect lasts for long due to reasons we can understand already:

- Higher TFP increases MPK, MPL (productivities) which makes investing more attractive
  - See how the output rises by more than 1%! This is both by the shock, but also by the higher capital stock
- Firms increase capital accumulation and thus output rises even in future periods when the shock may not be active anymore
- Also, this model accounts for the fact that several of these variables are persistent which leads to longer-lasting effects

Again, this kind of nuances are muted in the basic diagrams

Moreover, over these newly accounted-for effects are consistent with the economic mechanisms of the model and with the data!

The Dynamic Effects of a TFP Shock



Source: Frank Smets and Rafael Wouters, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol. 97, no. 3 (2007), pp. 586–606.

A Shock to Government Purchases

A temporary 1% increase in government purchases affects the economy: GDP, consumption, hours worked, and inflation.

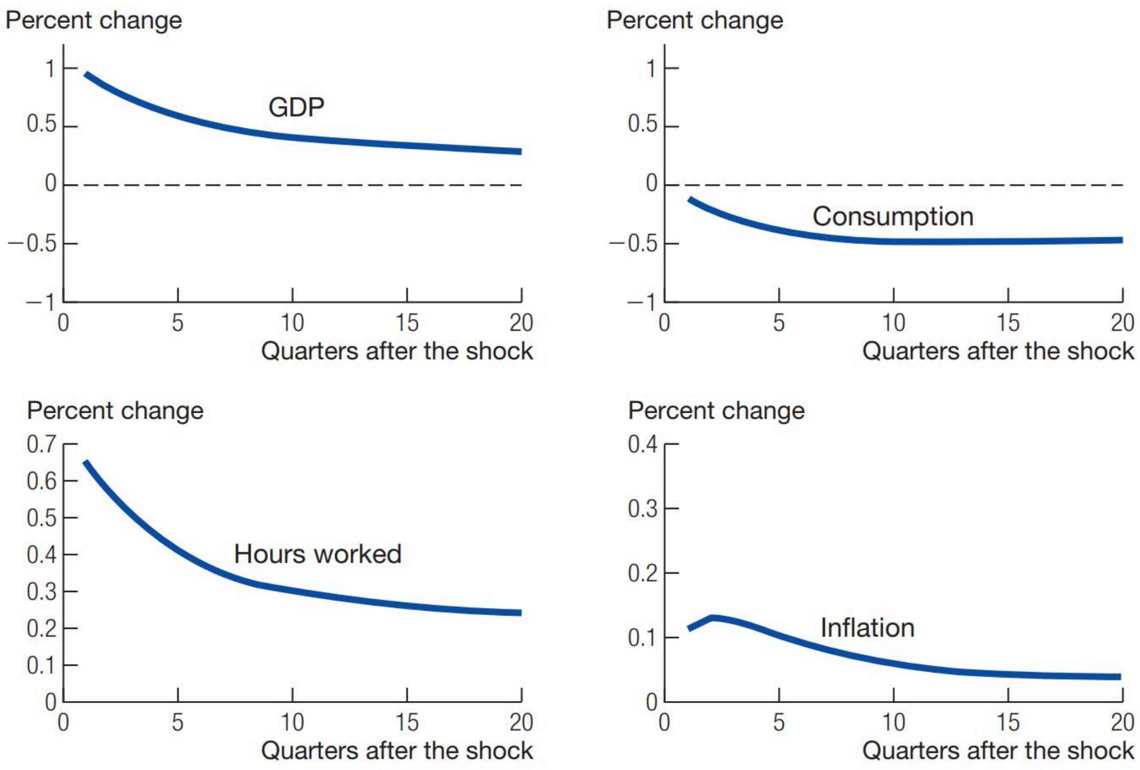
Impact on GDP:

- Initial impact of a 1% increase in government purchases results in approximately a 1% increase in GDP in the short run
- Effect diminishes over time as the temporary shock dissipates

Impact on Other Variables:

- **Consumption**: decline due to higher taxes and reduced household income
- **Hours Worked**: Increases due to higher labor demand
- **Inflation**: Remains relatively stable, showing only a slight increase initially and then stabilizing.

The Dynamic Effects of a Shock to Government Purchases



Source: Frank Smets and Rafael Wouters, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol. 97, no. 3 (2007), pp. 586–606.

This framework allows us to see how strikingly different it is to increase GDP via a higher productivity vs to higher expenditure (or lower taxes)

A Financial Friction Shock

Financial friction shock: introduces a **wedge between the interest rate** at which consumers save and borrow and FFR

This shock has a significant impact on consumption and is similar to a monetary policy shock

This shock is useful for understanding the GFC

In the model:
A microfounded mechanism is introduced for a market failure to explain the friction and to affect the economy endogenously!

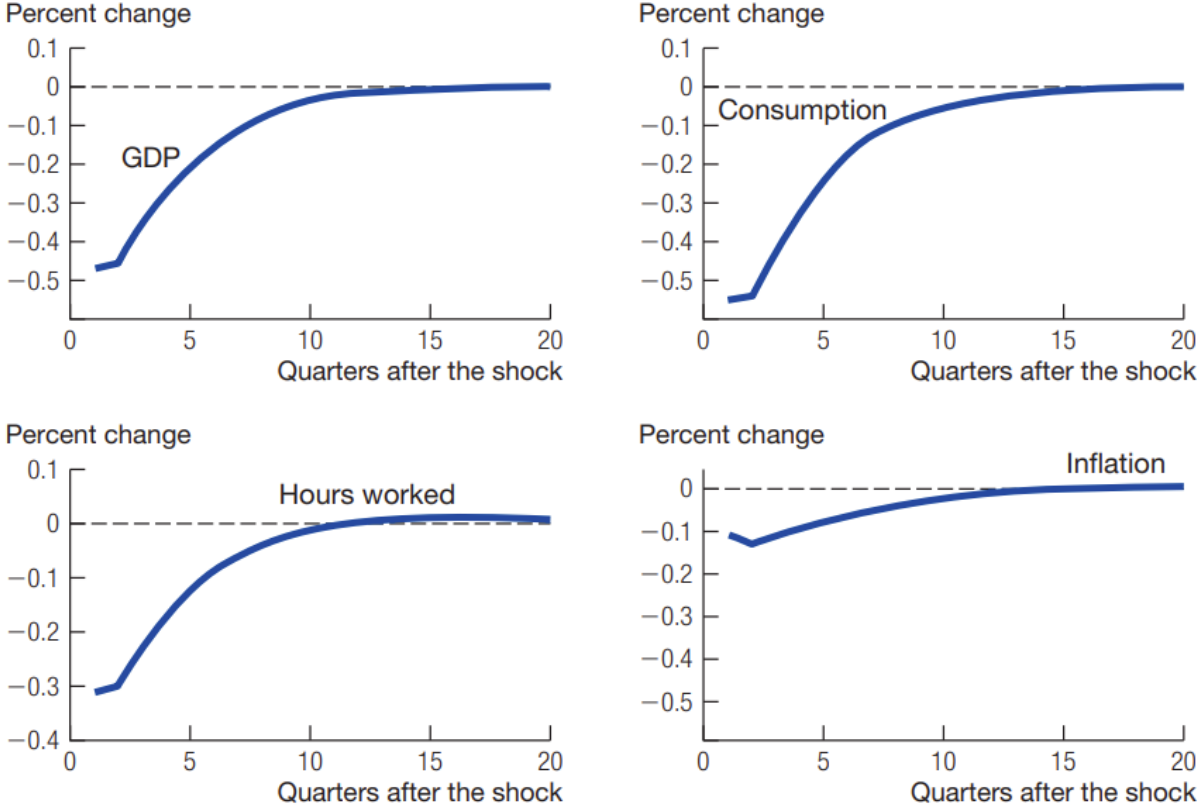
GDP: Declines after the financial friction shock and gradually returns to its original level.

Consumption: Notable initial decline but gradually recovery

Hours Worked: Also experience an initial drop, then rise slowly

Inflation: Slight decrease but remains relatively stable

The Dynamic Effects of a Financial Frictions Shock



Source: Frank Smets and Rafael Wouters, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol. 97, no. 3 (2007), pp. 586–606.

Conclusion

DSGE: Framework that accounts for more nuances of the economy (unlike prior approaches)

The importance of various shocks and frictions in economic fluctuations.

Quantitative significance of factors like wage and price stickiness, credit market frictions, and labor supply elasticity.

Consensus on Macroeconomic Framework:

Microfoundations: role of individual agents' decision-making in explaining aggregate macroeconomic outcomes

Enrichments to the Basic Framework:

- Inclusion of dynamics, expectations, uncertainty.
- But also of market failures: wage and price rigidities, credit market frictions, etc.

Now we can analyze features of the economy we were ignoring before: Transition dynamics, duration of shocks, magnitude of economic effects, etc.

Challenges in Quantitative Predictions:

- The models make precise predictions but often differ from real-world outcomes.
- Still a sizable gap between models and reality, but DSGE models remain crucial for future progress.

Importantly, the framework is under constant developments!

Appendix

Implications of Labor Supply Function

Wage and Consumption Ratio:

- Labor supply depends on the ratio of wage to consumption $\frac{w}{c}$.
- As real wages and consumption rise at similar rates, $\frac{w}{c}$ remains stable, implying a stable labor supply.

Parameter $\bar{l}$:

- The parameter $\bar{l}$ determines the overall magnitude of labor supply
- If c = w , then labor supply equals $\bar{l}$.

Utility Maximization:

- Labor supply curve: Derived from the individual's utility maximization problem, indicates how agents balance work (and thus more wage and consumption) and leisure.

Note: Another even more critical "balance" from the UMP is the one between Consumption and Saving and it's called the "Intratemporal" optimality condition as it refers to distributing resources over time (present vs. future consumption). In contrast, the consumption/leisure balance is called the "intratemporal" condition as it involves distributing (time resources —for work or for leisure) within the same period of time.