Monetary Policy

Part 1: Basic Macroeconomic Concepts

Lecture 3: Equilibrium Unemployment, Quantity Theory

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Outline

Part 1: Basic Macroeconomic Concepts

- Lecture 1: GDP Measurement, Growth and Business Cycles
- Lecture 2: The Long Run: Solow Model and Equilibrium Unemployment
- Lecture 3: The Long Run: Natural Interest Rate and Quantity Theory
- Lecture 4: The Short Run: The IS-MP-PC Model

Part 2: Conventional Monetary Policy

Part 3: Monetary Policy at the Zero Lower Bound on Nominal Interest Rate

Part 4: Monetary and Fiscal Interactions

Part 5: Financial Stability (if time permits)

Mock Exam

Learning Objective of Today‘s Lecture

We will review key determinants/theories of interest rates and inflation in the long run.

1. Understanding the natural interest rate and why its level is important for monetary policy

2. Getting to know methods for determining unobservable variables like potential output, the output gap, the natural interest rate and the NAIRU

3. Understanding inflation and the price level in the long run

Literature

Required reading

How central banks' interest rate setting follows long-run trends in interest rates caused by productivity growth, demographics and other (global) factors beyond the control of the central bank:

- Òscar Jordà and Allan Taylor (2019). Riders on the Storm. Federal Reserve Bank of San Francisco Economic Letter, 2019-29, https://www.frbsf.org/economic-research/files/el2019-29.pdf

Optional reading

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3.1 The Decrease in the Natural Interest Rate

Changes in the Long-Run Interest Rate

Recall the long-run interest rate based on the Solow Growth model:

$$r^* \approx \alpha\left(\frac{n + z + \delta}{s}\right)$$

The natural interest rate changes with factors that affect the demand for capital and the supply of savings:

- Capital intensity α
- Population growth rate n
- Technology growth rate z
- Depreciation rate δ
- Savings rate s

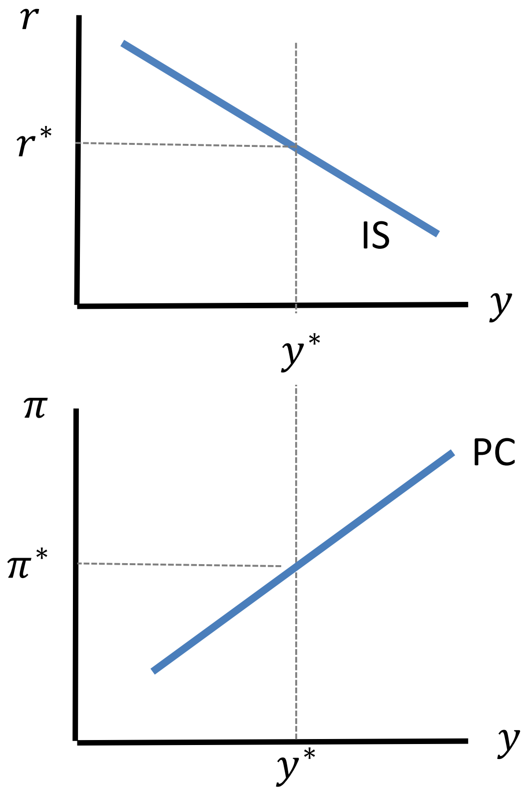
Increases in the first four increase the demand for capital, thereby increasing the natural rate of interest.

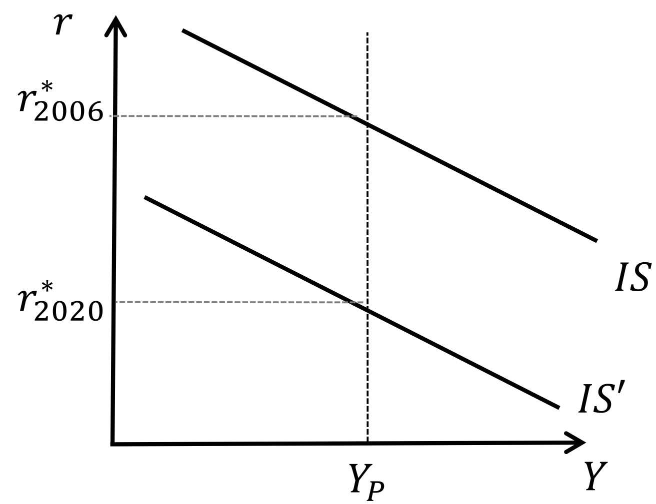
An increase in the savings rate increases the supply of savings, thereby decreasing the natural interest rate. In the Solow model the savings rate is exogenous. It could change for example with demographic change or persistent changes in public spending not offset by taxes.

Note that all drivers of the long-run interest rate are long-term developments in real variables.

What is the Natural Interest Rate?

- The concept of a natural rate of interest was originally introduced by Swedish economist Knut Wicksell (Wicksell, Interest and Prices, 1898): "There is a certain rate of interest on loans which is neutral in respect to commodity prices and tends neither to raise nor to lower them."
- The natural interest rate r^* is the rate which equates savings and investment at a level of output equaling potential output and inflation being stable. It is closely related to the long-run real interest rate.





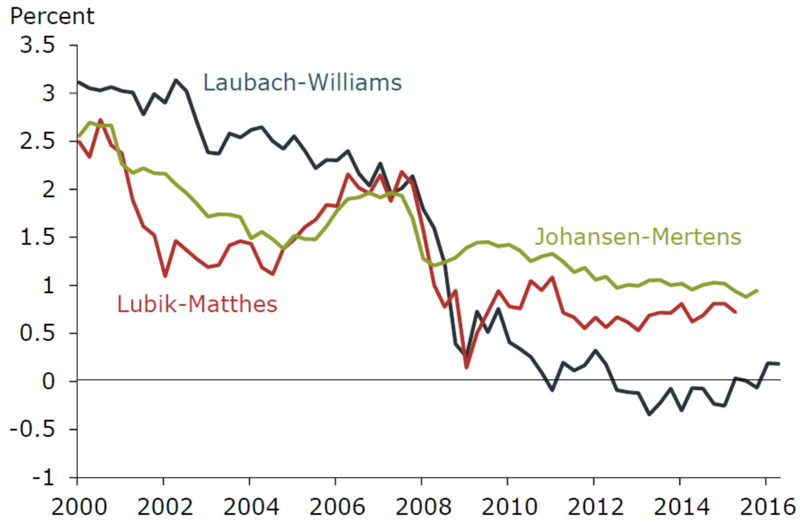
The Natural Interest Rate and the Probability of Hitting the ZLB

- Following the global financial crisis of 2008/2009, many central banks lowered their interest rate to the ZLB.
- In many countries policy rates have remained close to zero ever since.
- Inflation has been persistently low over the last decade.
- Many economists believe that the reason for the persistently binding ZLB is a decrease in the natural interest rate r^*.
- Recall that from the Fisher equation $i_t \approx r_t + \pi_t^e$. In the long-run $i^* \approx r^* + \pi^*$
- If r^* decreases, the ZLB binds with more frequency, which implies less room to maneuver for central banks
- The current decrease in the natural interest rate is thus one of the most important discussions in monetary policy nowadays.

Has the Natural Interest Rate Decreased?

- This question is not easy to answer. Similar to potential output, the output gap, and the NAIRU, the natural interest rate is a theoretical concept that is not directly observable.
- Economists have used a variety of different models to estimate changes in r^*
- It is not easy to distinguish changes in r_t that can be attributed to changes in r^*
- Most studies find a decrease in r^* over recent years, but the size of the decrease is highly disputed. The figure shows some examples focusing on the U.S.
- In particular, the estimates by Laubach and Williams had a very large impact on U.S. monetary policy.
- Studies for other economies like the euro area show overall similar developments.
- The uncertainty around estimates is extremely large.

Figure 2
Estimates of the neutral real interest rate



Source: Bauer and Rudebusch (2016)

- Note also that a decrease in the risk-free natural interest rate is found in the literature, while returns to capital seem to be stable. Hence, an increase in the demand for safe assets might be an important factor.

Possible Reasons for the Decline of r^*

1. Slowdown in long-run growth (Fernald, 2016) decreases the profitability of investment, leading to smaller investment demand.
   - The idea is not undisputed in the literature. While for example Gordon (2012) argues that productivity growth slows down due to stagnation of human capital's quality, pressures from globalization, and environmental issues, other argue that the digital revolution should impact productivity growth positively, but with a lag (e.g. Brynjolfsson and McAfee, 2014).

2. Surplus of global savings from export-based emerging market economies: Savings glut (Bernanke 2005).
   - Emerging economies implement macroeconomic policies to reduce their export-dependency.
   - As a side-effect, these economies acquire large amounts of savings by reducing their current account surplus. These large saving volumes are unmatched by investment opportunities and/or high-quality assets.

Possible Reasons for the Decline of r^*

3. Demographic factors tend to increase the supply of savings (Rachel and Smith, 2015).
   - A gradual population ageing induces people to accumulate more savings during their working lives so as to be able to pay for their retirement.

4. Increase in inequality might increase the supply of savings (Summers, 2014)
   - With increasing inequality a higher income share is concentrated in wealthy households that have a high propensity to save. Overall, this increases the supply of savings.

Empirically, it is very hard to say whether there is a *significant* decline in r^* and which drives this. Lunsford and West (2019), for example investigates long-run correlations between the real interest rate and over 20 explanatory variables and only find some correlations with two of them pointing to a role of shifts in demographics.

3.2 Estimating Unobservable Variables

Key Unobservable Variables

We are often interested in decomposing observable time series into cyclical and long-run components:

- GDP: trend vs. cycle
- Unemployment rate: cyclical variations vs. structural unemployment (NAIRU)
- Interest rate: cyclical variations vs. natural interest rate
- Inflation: cyclical variations vs. trend inflation

Changes in the two different components require different policies and are often modeled separately:

- Supply- vs. demand-oriented policies
- Models on long-run developments vs. business cycle models

Problem: How to split up one observable time series into two unobservable components?

- Often the long-run or structural component is estimated (methods on the next slides) and then the cyclical component is computed as the difference to the original time series.

Potential Output and the Output Gap: Unobservables

Potential output and the output are unobservable and need to be extracted from GDP, i.e. one time series is split up into two:

$$y_t = g_t + c_t$$

y_t: log real GDP

g_t: log potential real GDP

c_t: output gap (percentage deviation of actual GDP from potential GDP)

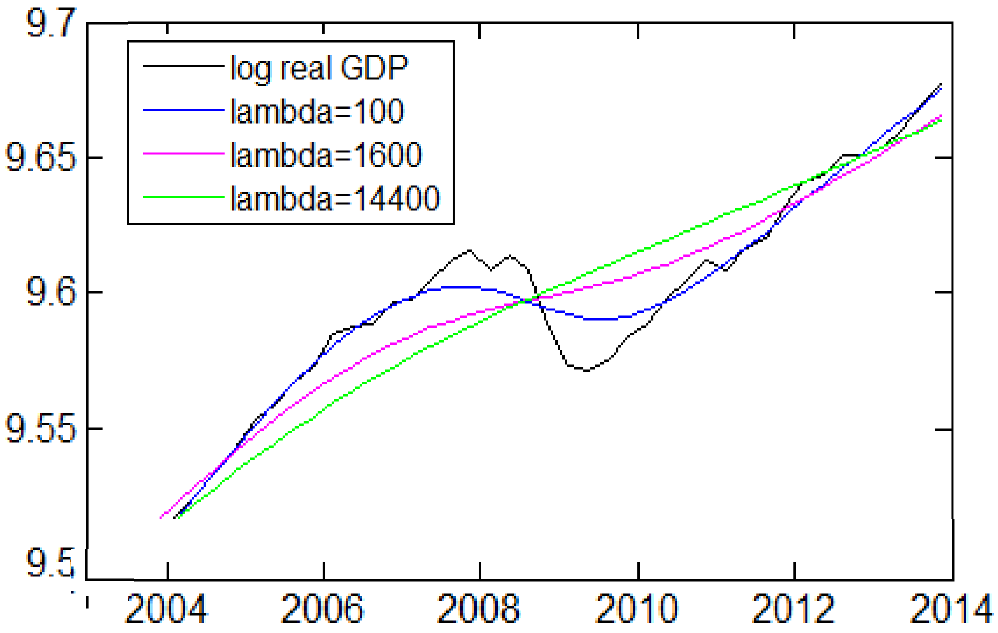
- Measuring potential output is essential for growth-oriented policy measures and for projecting GDP over medium horizons (3 to 5 years) as over time cyclical factors fade out (supply and demand converge).
- Measuring the output gap is important for business cycle analysis and stabilization policies.

Two-Sided Filtering Techniques: Example 1, HP Filter

- It computes trend as:

$$\min_{\{g_t\}_{t=-1}^{T}} \left\{ \sum_{t=1}^{T} c_t^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right\}$$

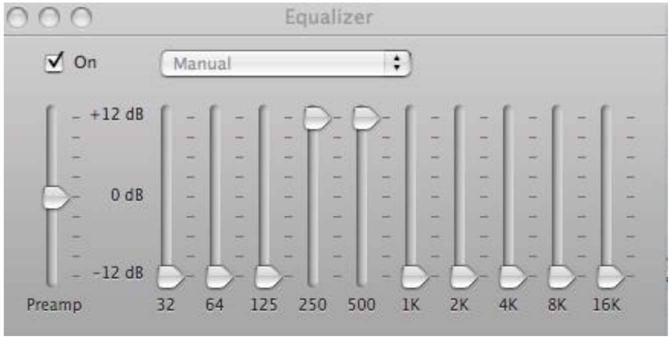
- There is a trade off between attributing more variation in GDP to business cycle dynamics (very smooth trend) or to long-run fluctuations (more flexible adjustment of trend component).
- The trade-off is solved by the choice of the parameter λ.
- The higher λ, the smoother the trend.
- Standard value for quarterly data: $\lambda = 1600$



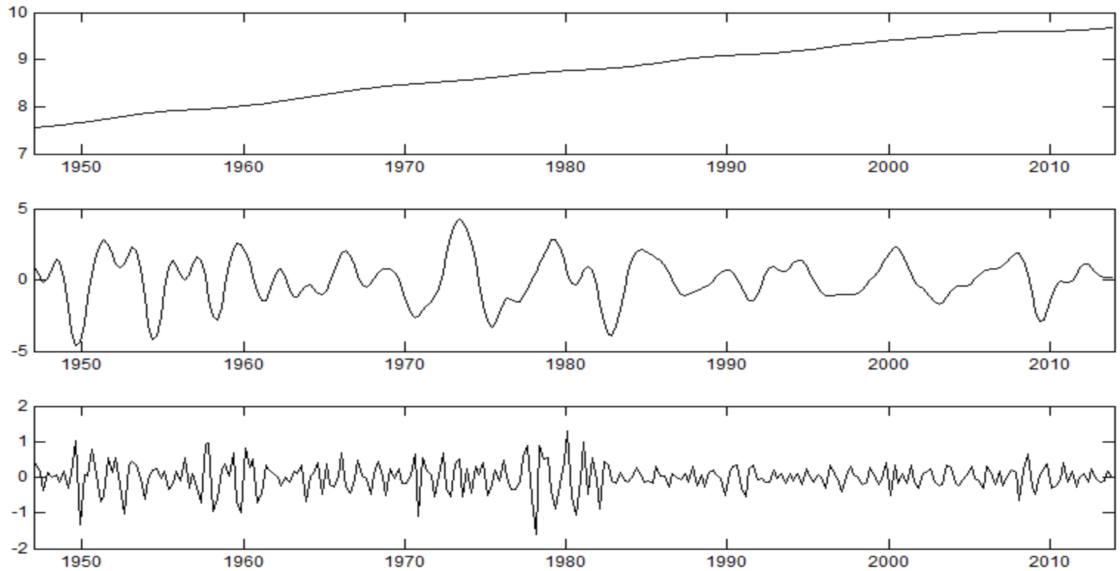
Source: own computation

Two-Sided Filtering Techniques: Example 2, Bandpass Filter

- Transform GDP into the frequency domain and filters out dynamics on business cycle frequencies (typically cycles ranging from 6-32 quarters length)



- Splits up log real GDP into a trend, a cycle and an irregular component



One-Sided Filtering Techniques

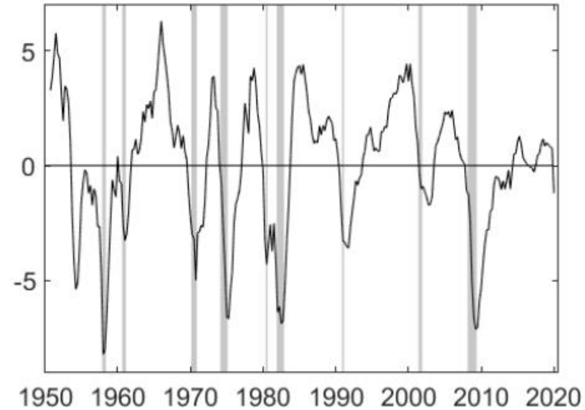
One-sided filtering techniques: Only past observations of GDP are used, so that there are no revisions if new data becomes available (apart from those induced by data revisions)

Hamilton Filter (Hamilton, 2018)

- Trend amounts to a simple two-year forecast of GDP based on an autoregressive forecasting model
- Cycle amounts to unexpected dynamics such as recessions.
- Estimate with OLS: $y_t = \beta_0 + \beta_1 y_{t-8} + \beta_2 y_{t-9} + \beta_3 y_{t-10} + \beta_4 y_{t-11} + \varepsilon_t$
- Trend: $\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 y_{t-8} + \hat{\beta} y_{t-9} + \hat{\beta}_3 y_{t-10} + \hat{\beta}_4 y_{t-11}$
- Cycle: $\hat{\varepsilon}_t = y_t - \hat{y}_t$

Modified Hamilton Filter (Quast and Wolters, 2021)

- Similar to Hamilton filter, but rather than using a fixed 8-quarter horizon, average across 4- to 12-quarter ahead forecasts is used
- Leads to a better coverage of typical business cycles in the output gap.
- Both methods yield real-time output gap estimates that are highly correlated with ex post estimates by policy institutions (Fed, IMF, OECD)



US Real-time Output Gap

Unobserved Component Models

Small semi-structural models that link unobservable variables (trend and cycle) to observable ones:

Example 1:

$$y_t = y_t^p + c_t$$
$$c_t = \alpha c_{t-1} + \beta c_{t-2} + \varepsilon_t^c$$
$$y_t^p = y_{t-1}^p + \delta + \varepsilon_t^p$$

Observable is only y_t, all parameters and y_t^p (potential GDP) and c_t (cyclical component) are estimated.

Example 2:

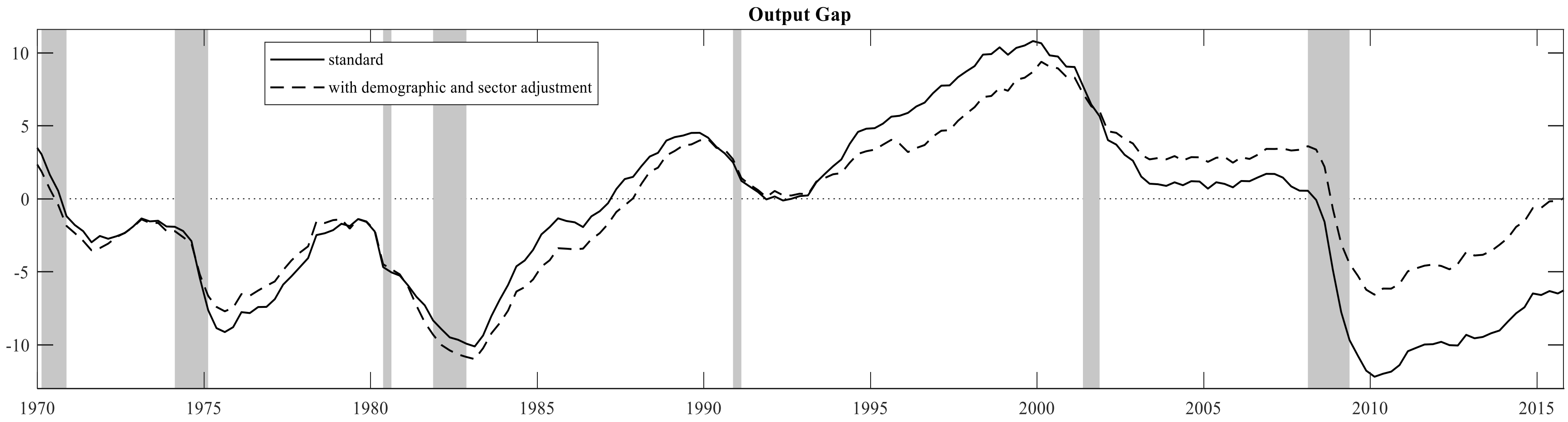
$$y_t = y_t^p + c_t$$
$$c_t = \alpha c_{t-1} + \beta c_{t-2} + \varepsilon_t^c$$
$$y_t^p = y_{t-1}^p + \delta + \varepsilon_t^p$$
$$\Delta\pi_t = \xi_1 + \xi_2 c_{t-1} + \varepsilon_t^\pi$$

Observables are y_t and $\Delta\pi_t$

- High number of parameters can lead to high estimation uncertainty.
- Results are prone to revisions similar to those based on two-sided filtering techniques.

Dynamic Stochastic General Equilibrium (DSGE) Models

- Theory-based models typically used at central banks. Equations are based on optimality conditions of microeconomic optimization problems of households and firms.
- Expectations play an important role and need to be solved for. Often the assumption of rational expectations is used.
- Model can often not capture medium term cycles, stemming for example from demographic and sectoral change. This can distort output gap estimates:



Source: Wolters (2018), How the Baby Boomers' Retirement Wave Distorts Model-Based Output Gap Estimates, *Journal of Applied Econometrics,* 2018, 33(5): 680-689.

Methods for Estimating the Natural Interest Rate

Unobserved Components Model

- Setting up a model including observable variables (like output y_t,inflation π_t, nominal interest rate i_t, etc.)
- Long-run values like y^* and r^* are estimated together with the parameters of exogenous shocks of the model.
- If the model implied values for y_t, π_t and i_t deviate from the observed data, the estimation algorithm would adjust y^* and r^* in a way that brings the model and the data in line with each other.
- This is the most common approach for estimating the natural interest rate. In particular, many papers build on the approach by Laubach and Williams (2003).
- Two caveats of this approach:
    1. Many parameters and unobservable variables are estimated on few observables. The estimation uncertainty is very high.
    2. The time series processes assumed for specific unobservables can have a high impact. A small change of the Laubach and Williams model can change the estimates of r_t^* substantially (see Beyer and Wieland 2019, Kiley 2020)

Methods for Estimating the Natural Interest Rate

Vector Autoregressions

- A Vector Autoregression (VAR) can capture dynamic correlations among many variables (output growth, inflation and the real interest rate) without imposing coefficient restrictions from theory.
- One can estimate VARs with time-varying parameters to capture secular change over time.
- A VAR does not include unobservable variables like r^*. The value of r^* can, however, be inferred if one defines it as the value of the real interest rate that occurs over the medium run after shocks have faded out. r^*can then be estimated based on a forecast of r_t.
- Example: Lubik and Matthes (2015) use a VAR with time-varying parameters and compute five-year forecast for the real interest rate. They assume that over a five-year horizon the real interest rate converges to its natural counterpart.

Methods for Estimating the Natural Interest Rate

DSGE Models

- DSGE models are basically large unobserved components models. Equations are derived from microeconomic optimization problems of households and firms and expectations play a key role for macroeconomic dynamics.
- The models are estimated on a limited set of observable variables. Time series for unobservable variables like r^* are estimated together with the parameters of the model.
- A big advantage is that the factors driving r^* are all clearly defined.
- r^* is, however, usually not time-varying in these models. Either one can use the forecasting approach for r_t (see for example, Del Negro et al., 2017), as in the VAR-based literature or one can estimate the model based on different subsamples.

3.3 Inflation in the Long Run

Quantity Theory

The starting point of the classical quantity theory is the quantity equation

$$V \times M = Y \times P$$

- V: velocity of money, how many times does money change hands: $V = (Y \times P)/\mathrm{M}$
- Y: real GDP
- P: price
- M: money in circulation

- The left-hand side shows the nominal value of all transactions in a given time period
- The right-hand side shows nominal GDP, i.e. the value of all final goods and services sold in a given time period
- This means both sides show the same, just measured differently
- The quantity equation is an identity. It always holds. It is just a matter of measuring the variables correctly.

Quantity Theory

Quantity equation: $V \times M = Y \times P$

Assumptions of the Quantity Theory:

- M is controlled by the central bank
- V and Y are independent of M (this is a theory about the long run!).
- V is a variable that might change with financial transaction technology (credit cards, ATM etc.), but can otherwise be expected to be rather constant.
- We have studied the determinants of Y in last week's lecture. M did not show up.

Quantity Theory

Quantity theory implies:

- An increase in M by the central bank by x percent increases the price level by the same x percent.

$$\frac{\bar{V}M}{\bar{Y}} = P$$

- In growth rates

$$\pi = g_m + g_v - g_y \overset{g_v \approx 0}{\overbrace{=}} g_m - g_y$$

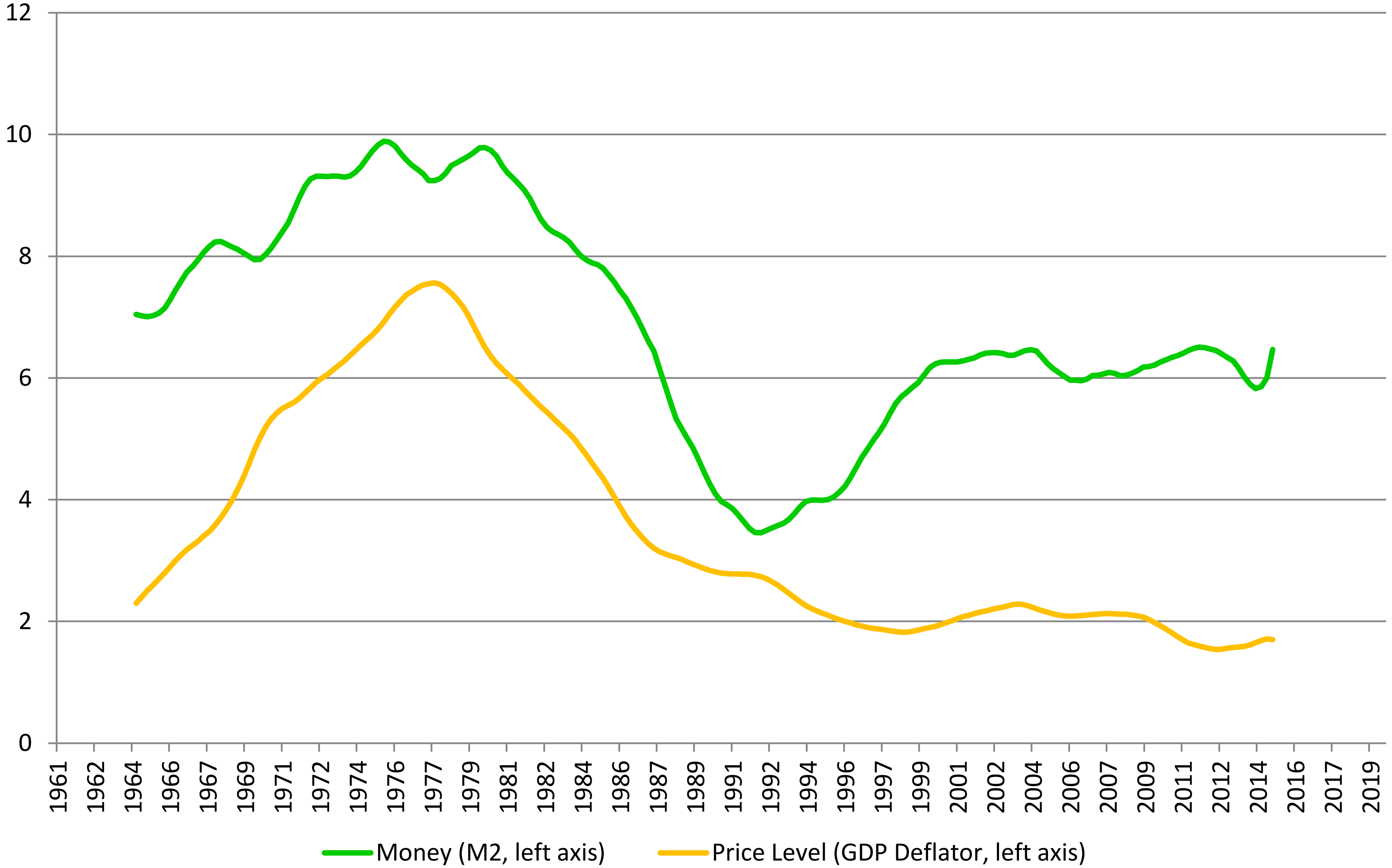
Punchline: Inflation is controlled by the central bank in the long run.

Real growth in the economy ($g_y > 0$) leads to more transactions, requiring more money.

However, growth in money in excess of real growth of the economy ($g_m > g_y$) leads to an increase in prices. We will discuss in a later lecture the optimal level of inflation.

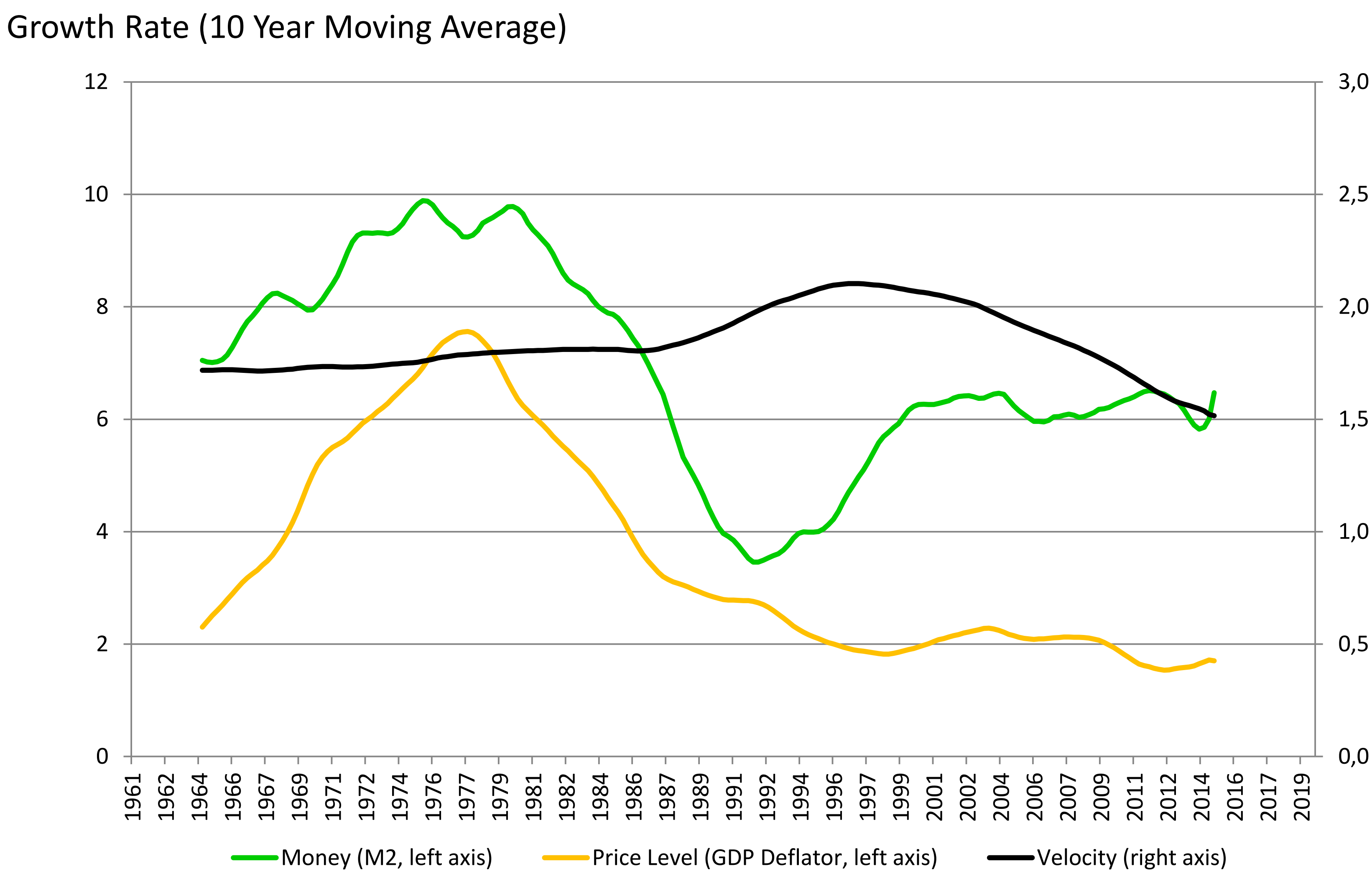
Quantity Theory Empirically (U.S. Data)

Growth Rate (10 Year Moving Average)



Source: St. Louis Fed, own computations

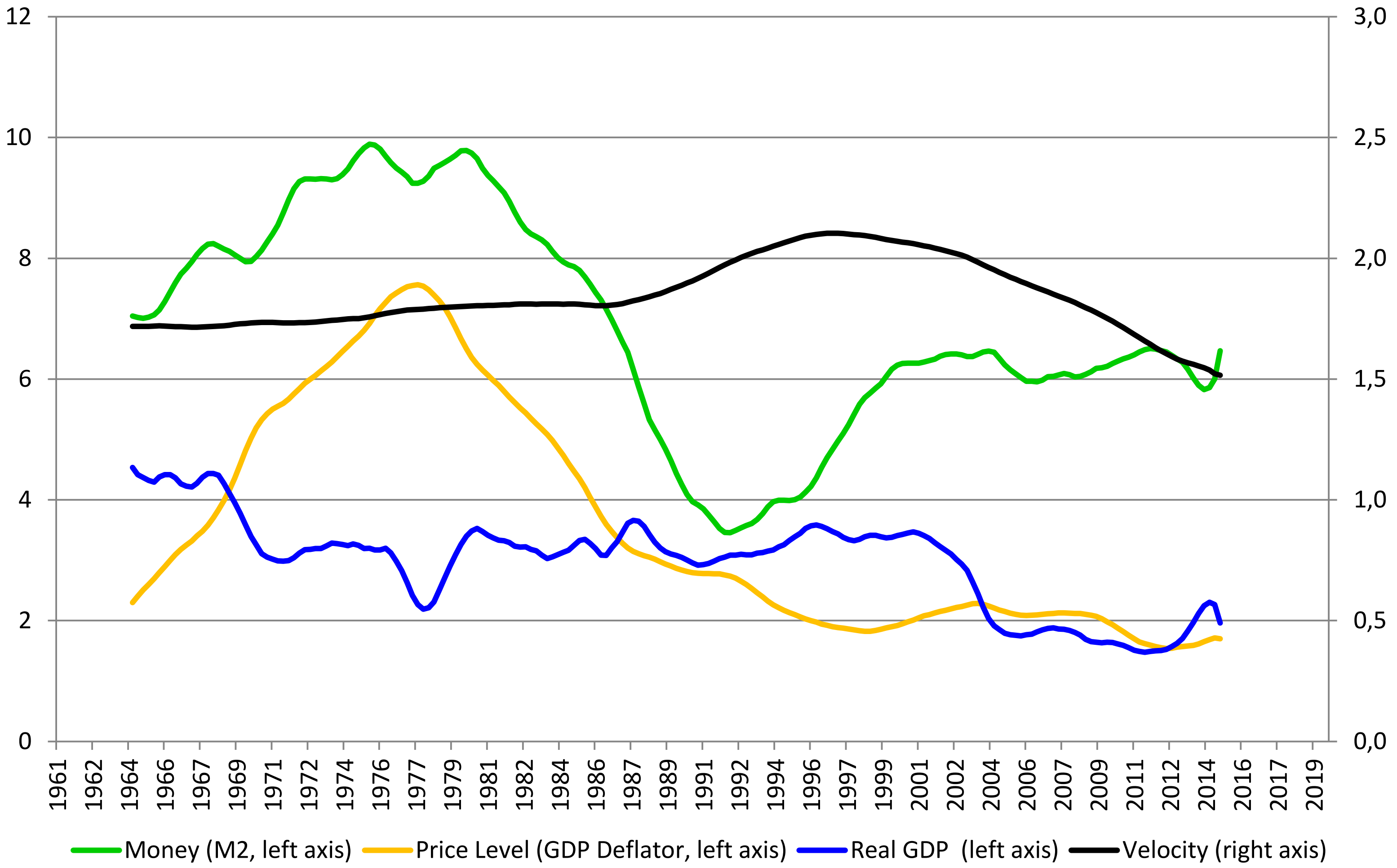
Quantity Theory Empirically (U.S. Data)



Source: St. Louis Fed, own computations

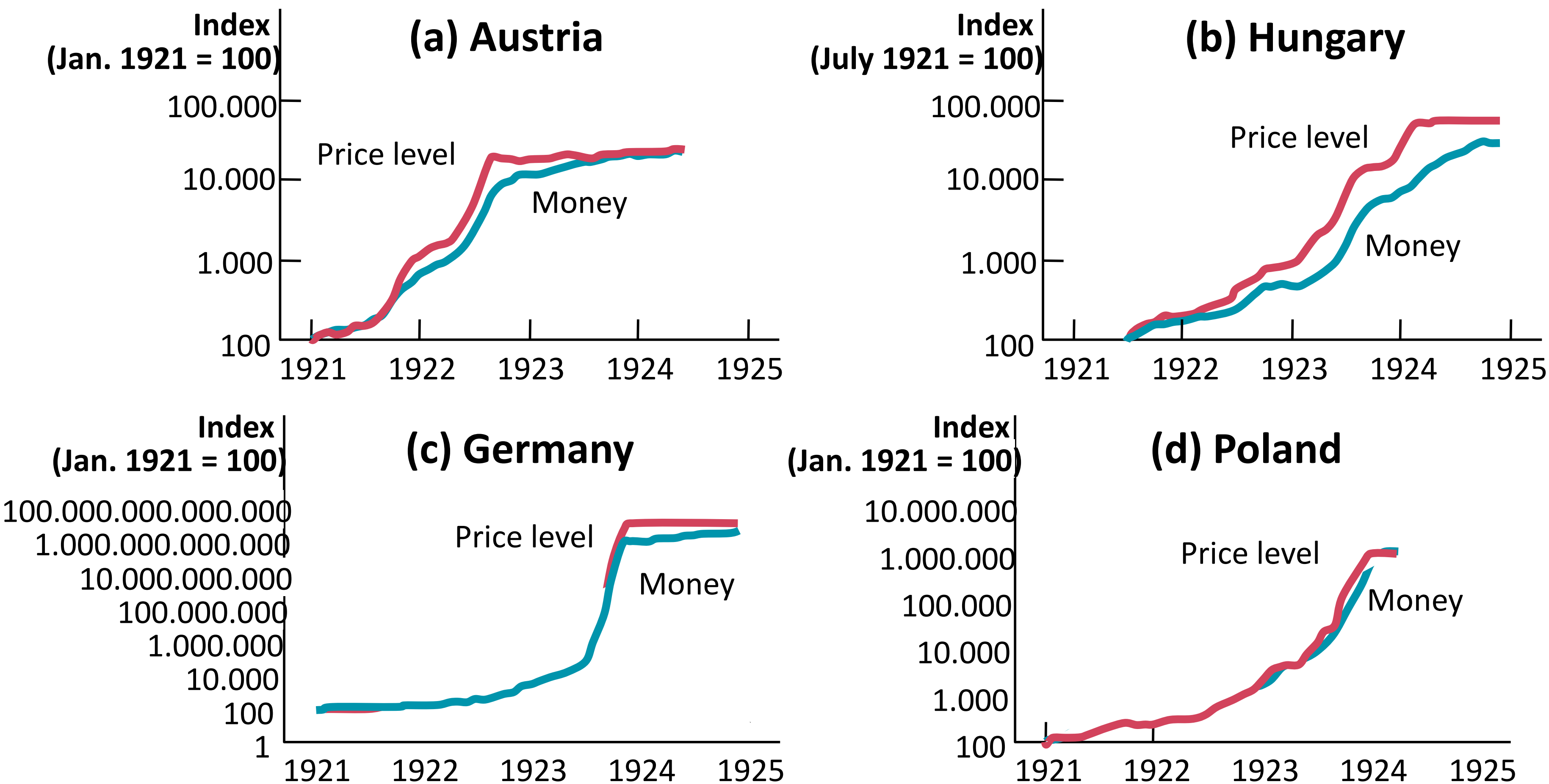
Quantity Theory Empirically (U.S. Data)

Growth Rate (10 Year Moving Average)



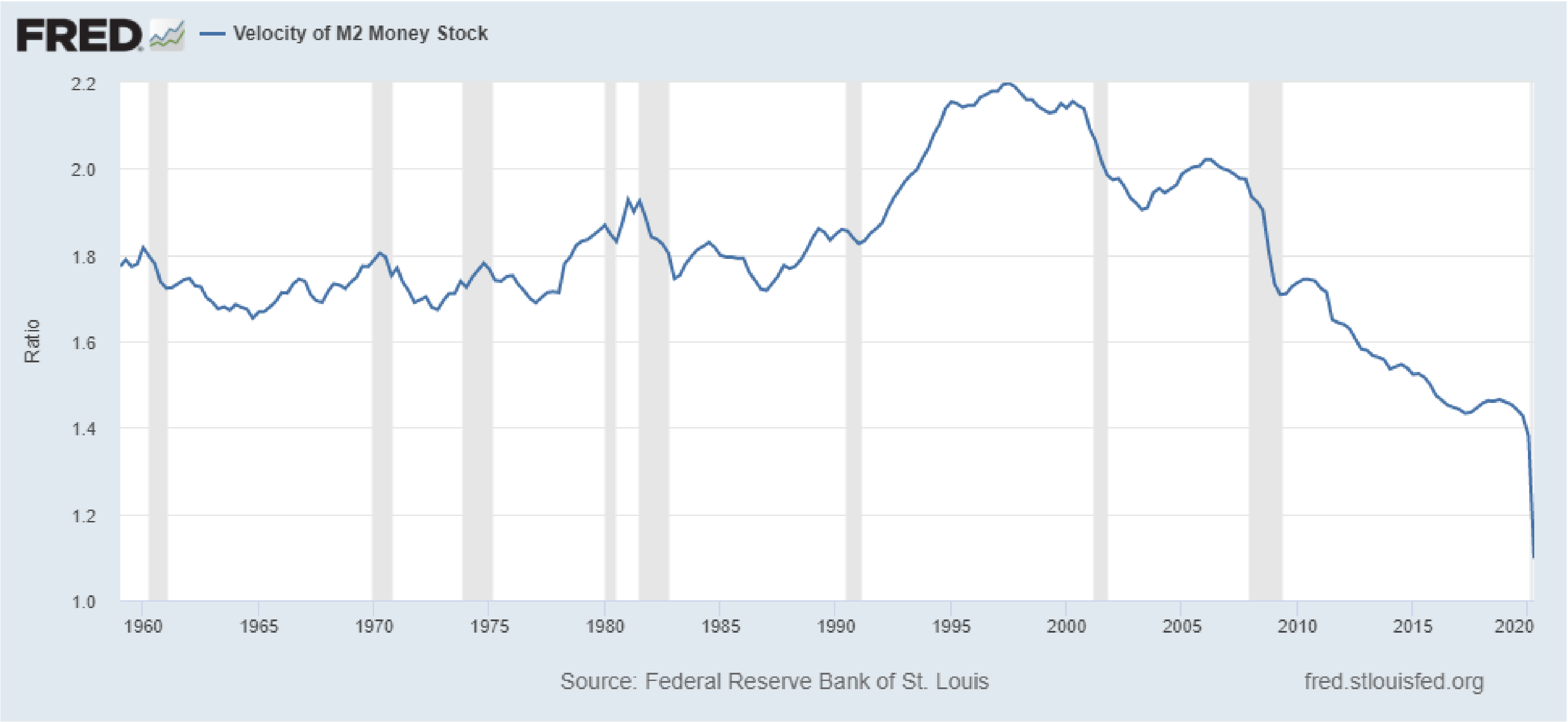
Source: St. Louis Fed, own computations

Money and Price Level during Hyperinflation



Why is Inflation Currently Not Increasing, Despite Massive Monetary Stimulus?

- Money hoarding leads to declining velocity of money. Possible reasons: precautionary savings, deleveraging, low investment dynamics.
- This often happen during financial crises (ex. Great Depression, Great Recession).
- The example shows data for the U.S., but similar developments elsewhere.



Summary

The natural interest rate r^* is the interest rate at which investment and savings are in equilibrium and inflation is stable. It changes with factors affecting the demand for investment like changes in technology growth and the supply of savings like changes in demographics.

- Estimates show that r^* has decreased since the Global Financial Crisis.
- This implies that the average nominal interest rate has decreased ($i^* \approx r^* + \pi^*$), so that the ZLB binds more frequently compared to the past. It is one of the most important topics in central banking.

There is a variety of methods for estimating unobservable long-run concepts like potential output (implying the output gap), the NAIRU, the natural interest rate, trend inflation etc.

- Needed to separate short- and long-run developments with diverging policy implications.
- Difficult to distinguish trend and cycle in particular in real time.

The Quantity Theory shows that inflation is driven by money supply in the long run

The analysis of lectures 2 and 3 shows that real and nominal variables can be analyzed separately for long-run developments.

- This gives rise to vertical long-run AS and Phillips curves.
- Monetary policy affects only nominal variables in the long run but has no effect on real variables.