Topic 2: Inflation

Monetary Economics

ECOS3010

Measuring Money

- The definition of money as anything that is generally accepted in payments for goods and services does not tell us how we should measure money.

- Which assets shall we include when we measure money? Each country's central bank provides precise definitions.
- In Australia, the Reserve Bank of Australia (RBA) is responsible for monetary policy.

Measuring Money

- RBA's definition of monetary aggregates:
  - currency: notes and coins held by the private non-bank sector;
  - M1: currency + current deposits with banks;
  - M3: M1 + all other deposits at banks;
  - Broad money: M3 + other borrowings from private sector by AFIs.
- In general, currency $\preceq$ M1 $\preceq$ M3 $\preceq$ broad money.

Introduction: Inflation

- In our simple model of money, money supply is constant. From data on monetary aggregates, money supply seems to grow over time.
- The supply of fiat money is usually controlled by the central bank. Printing new money is an important way to finance government spending needs.

- In this topic, we will examine
  - the consequences of increasing money supply;
  - the link between government spending and inflation;
  - seigniorage: theory and evidence.

Some Evidence

- Money growth is the main determinant of inflation.
- A few examples of extraordinarily high inflation rates – hyperinflations:
  - Germany in 1923: inflation hits 3.25×10^6 percent per month $\longrightarrow$ prices double every two days;
  - Greece between 1941 and 1944: inflation hits 8.55×10^9 percent per month $\longrightarrow$ prices double every 28 hours;
  - Yugoslavia between Oct 1993 and Jan 1994: inflation hits 5×10^{15} percent per month $\longrightarrow$ prices double every 16 hours;
  - Hungary after the end of WWII: inflation peaks at 4.19×10^{16} percent per month $\longrightarrow$ prices double every 15 hours;
  - other examples include eastern European countries in the period of economic transition in the early 1990s, Chile from 1972 to 1974, Mexico from 1982 to 1988, and ..... A more recent example is Zimbabwe.

Australian Inflation

Some Evidence

- There could also be deflation. Examples:
  - United States from 1930 to 1933;
  - Hong Kong from late 1997 to 2004;
  - Japan in the early 1990s.
- To understand the causes and consequences of changing money growth rate, we will develop a theory.

A Growing Money Supply: New Money to the Public

- Consider the OLG economy that we developed so far. Suppose that money supply grows at a rate z

$$M_t = zM_{t-1}.$$

- The amount of new money introduced into the economy in period t is

$$M_t - M_{t-1} = M_t - \frac{M_t}{z} = \left(1 - \frac{1}{z}\right) M_t.$$

- New money is introduced into the economy by means of *lump-sum* transfers to each **old** individual in every period t worth a_t units of consumption goods.

- To find the value of a_t, in aggregate the government budget constraint is

$$N_{t-1} a_t = \left(1 - \frac{1}{z}\right) v_t M_t.$$

$$\Rightarrow a_t = \frac{\left(1 - \frac{1}{z}\right) v_t M_t}{N_{t-1}}.$$

A Growing Money Supply: New Money to the Public

A Monetary Equilibrium

- Budget constraints:
  - first period of life

$$c_{1,t} + v_t m_t \leq y,$$

  - second period of life

$$c_{2,t+1} \leq y_{t+1} m_t + a_{t+1},$$

  - lifetime budget constraint

$$c_{1,t} + \frac{v_t}{v_{t+1}} c_{2,t+1} \leq y + \frac{v_t}{v_{t+1}} a_{t+1}.$$

- What is the value of v_{t+1}/v_t? As before, we first solve for v_t from money market clearing condition.

$$v_t M_t = N_t (y - c_{1,t}) \quad \rightarrow \quad v_t = \frac{N_t (y - c_{1,t})}{M_t}.$$

A Growing Money Supply: New Money to the Public

A Monetary Equilibrium

- As usual, we focus on stationary allocations. **Assume for now that the population is constant.**
- The value of money is then

$$v_t = \frac{N(y - c_1)}{M_t}.$$

It follows that

$$\frac{v_{t+1}}{v_t} = \quad .$$

Furthermore, the price level

$$\frac{p_{t+1}}{p_t} = \frac{\frac{1}{v_{t+1}}}{\frac{1}{v_t}} = \frac{v_t}{v_{t+1}} = z.$$

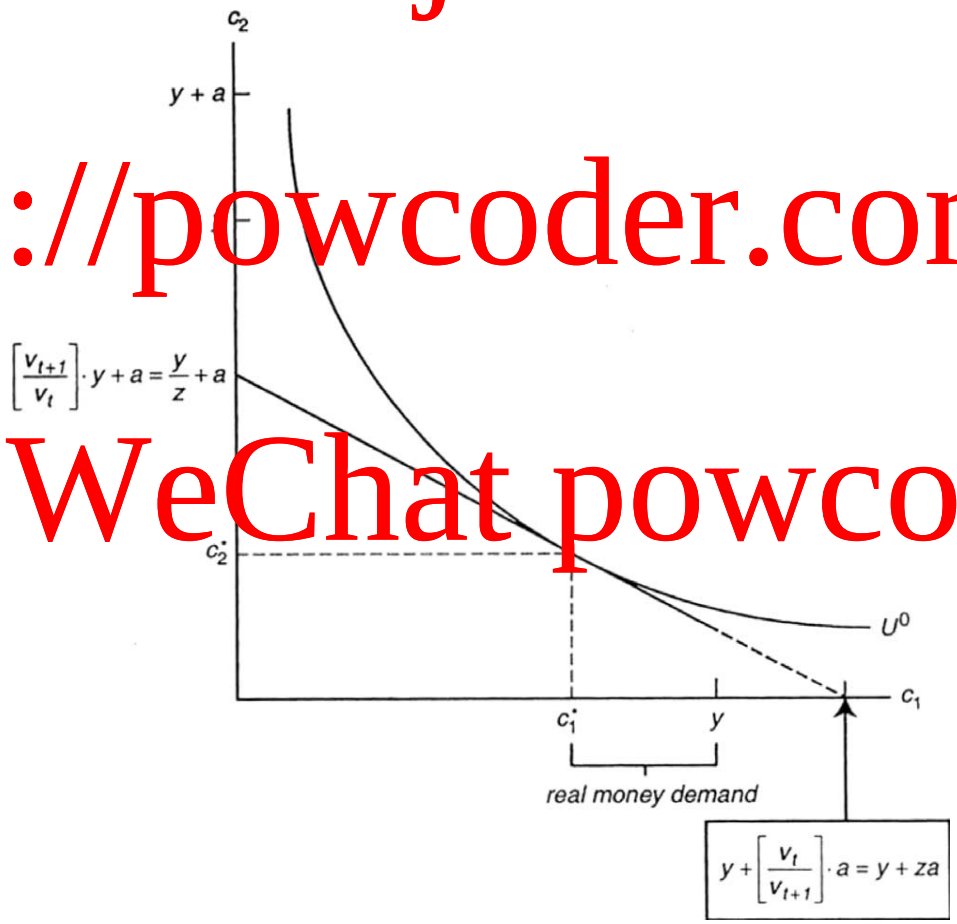
- When money supply is growing at a rate z, the price level increases at a rate z. **Quantity Theory of Money!**

A Growing Money Supply: New Money to the Public

A Monetary Equilibrium

- An individual's budget constraint simplifies to

$$c_1 + zc_2 \leq y + za$$



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A Monetary Equilibrium

- The solution (c_1^*, c_2^*) are functions of (z, y, a). To close the model, we need to find the value of a. Recall that from the government budget constraint

$$N_{t-1} a_t = \left(1 - \frac{1}{z}\right) v_t M_t.$$

a is solved from

$$a = \frac{\left(1 - \frac{1}{z}\right) v_t M_t}{N} = \frac{\left(1 - \frac{1}{z}\right) \frac{N(y - c_1)}{M_t} M_t}{N} = \left(1 - \frac{1}{z}\right)(y - c_1^*).$$

- In a monetary equilibrium, (c_1^*, c_2^*) maximizes an individual's utility subject to the lifetime budget constraint. The government transfer a is such that the government budget constraint is **satisfied** in every period.

A Growing Money Supply: New Money to the Public

A Monetary Equilibrium: an Example

- An example: if $u(c_1, c_2) = c_1 c_2$, an individual

$$\max_{c_1, c_2} c_1 c_2 \text{ subject to } c_1 + z c_2 \leq y + za.$$

Following similar steps as we did in last lecture, we have

$$c_1 = \frac{y + za}{2} \text{ and } c_2 = \frac{y + za}{2z}.$$

We can also find a by solving

$$a = \left(1 - \frac{1}{z}\right)\left(y - \frac{y + za}{2}\right) \rightarrow a = \frac{y\left(1 - \frac{1}{z}\right)}{1 + z}.$$

Substituting a into (c_1, c_2), we have

$$c_1 = \frac{yz}{1+z} \text{ and } c_2 = \frac{y}{1+z}.$$

A Growing Money Supply: New Money to the Public

Is the Monetary Equilibrium Efficient?

- Consider the model with a constant population and a growing money supply, $M_t = zM_{t-1}$.
- An individual's budget constraint

$$c_1 + zc_2 \leq y + za$$

- The golden rule allocation: a planner maximizes an individual's utility subject to the resource constraint.

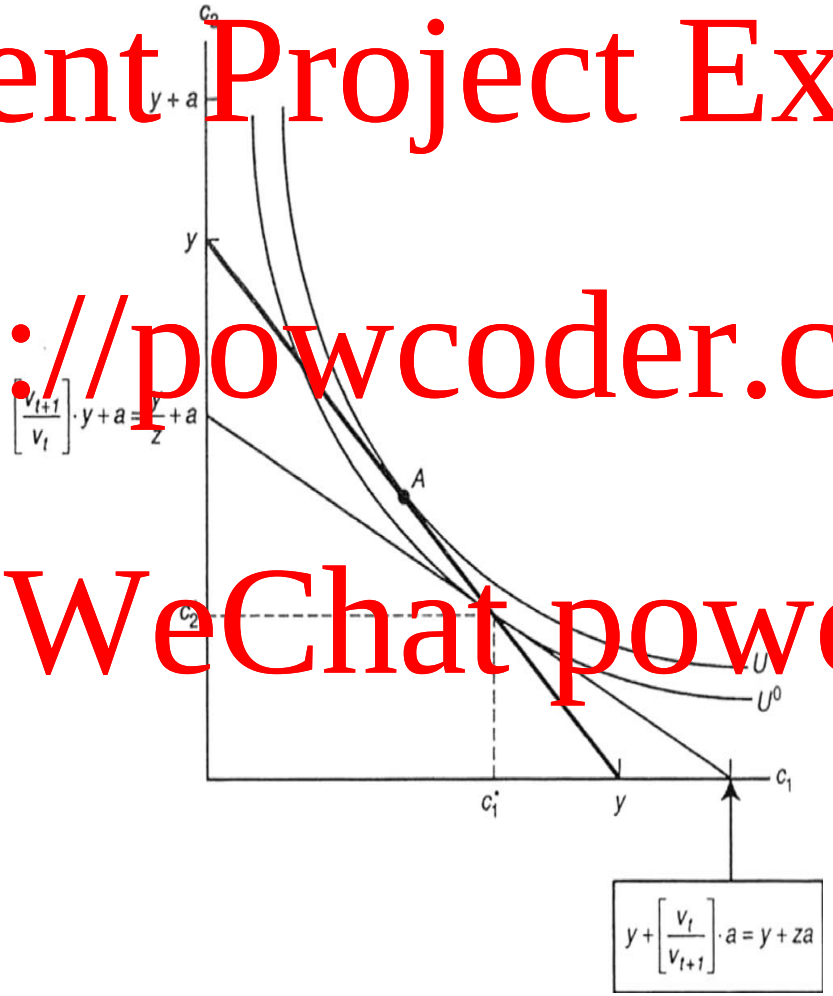
Resource constraint

$$Nc_1 + Nc_2 \leq Ny \quad \rightarrow \quad c_1 + c_2 \leq y.$$

A Growing Money Supply: New Money to the Public

Is the Monetary Equilibrium Efficient?

Graphically,



- Compare monetary equilibrium allocation at point B with the golden rule allocation at point A.
- Monetary equilibrium at point B: intersection of the budget constraint and the resource constraint. Why?

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Is the Monetary Equilibrium Efficient?

- With a growing money supply, the allocation in a monetary equilibrium is not the golden rule allocation.
  - Young consume more $\longrightarrow$ noncash goods.
  - Old consume less $\longrightarrow$ cash goods.

- In a monetary equilibrium, all future generations are worse off: utility at point B is lower than utility at point A. The initial old are also worse off.

- Some more to think about
  - Why don't individuals choose point A?
  - What is the optimal growth rate of money supply?

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Cost of Inflation

- In general, effects of inflation:

people are less willing to hold money & economize the use of money,

↓

transactions that are conducted using money are adversely affected,

↓

violates "smooth consumption" assumption

↓

welfare fall.

- Inflation is effectively a tax.

A Growing Money Supply: New Money to the Public

A Growing Population

- Suppose that population grows such that $N_t = nN_{t-1}$.
- Budget constraints:
  - first-period budget constraint: $c_1 + v_t m_t \leq y$;
  - second-period budget constraint: $c_2 \leq v_{t+1} m_t + a$;
  - lifetime budget constraint:

$$c_1 + \frac{v_t}{v_{t+1}} c_2 \leq y + \frac{v_t}{v_{t+1}} a.$$

Value of money v_t:

$$N_t (y - c_1) = v_t M_t \quad \rightarrow \quad v_t = \frac{N_t (y - c_1)}{M_t}.$$

- Money's rate of return v_{t+1}/v_t:

$$\frac{v_{t+1}}{v_t} = \frac{\frac{N_{t+1}(y-c_1)}{M_{t+1}}}{\frac{N_t(y-c_1)}{M_t}} = \frac{N_{t+1}}{N_t}\frac{M_t}{M_{t+1}} = \frac{n}{z}.$$

The value of money may increase or decrease over time depending on the values of n and z.

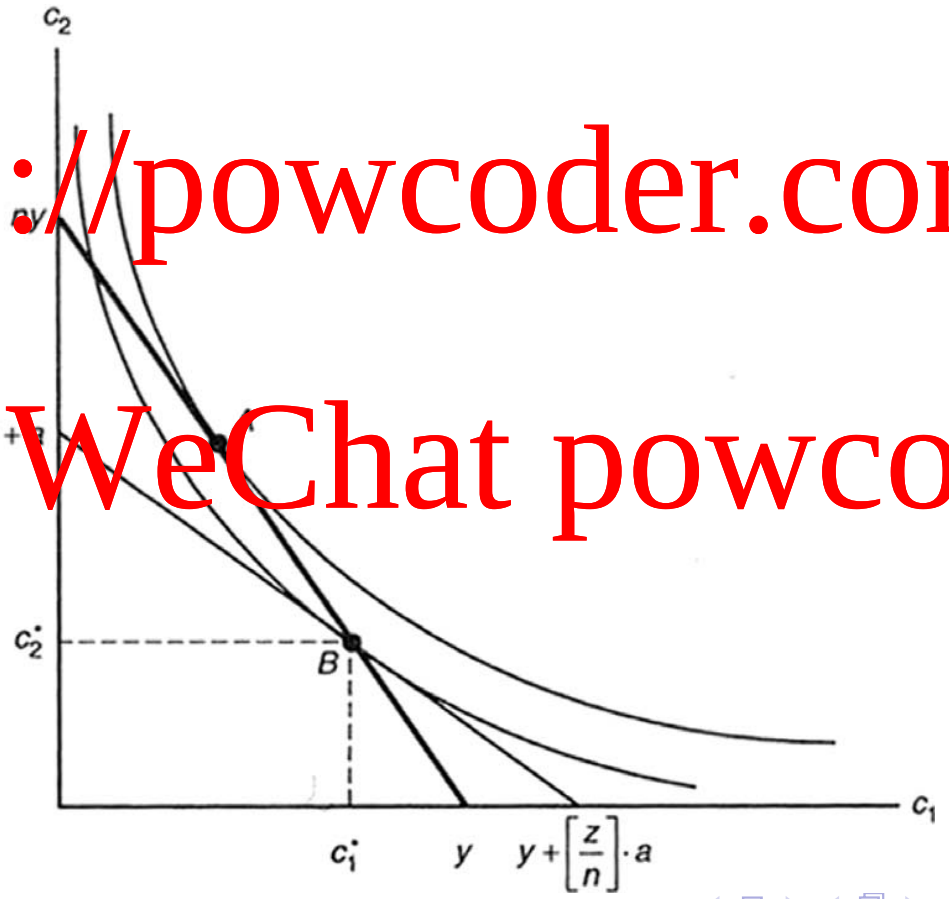
An individual's lifetime budget constraint simplifies to

$$c_1 + \frac{z}{n}c_2 \leq y + \frac{z}{n}a.$$

A Growing Money Supply: New Money to the Public

A Growing Population

- Graphically, we depict the budget constraint and the allocation B that is chosen in a monetary equilibrium. Allocation A is the golden rule allocation.



- Golden rule allocation: a planner's resource constraint

$$N_t c_1 + N_{t-1} c_2 \leq N_t y \quad \rightarrow \quad c_1 + \frac{1}{n} c_2 \leq y.$$

- The resource constraint is different from the individual's budget constraint. The allocation in a monetary equilibrium is not the golden rule allocation. Again, the expansion of money supply makes individuals consume more when young and less when old. The overall utility is lower than the utility at the golden rule allocation.

A Growing Money Supply: New Money to the Public

Exercise:

Consider the case in which government set $z = n$, which implies $\frac{v_{t+1}}{v_t} = \frac{n}{z} = 1$. The value of money and the price level are constant in this case. Is the monetary equilibrium efficient?

- What is the optimal growth rate of money supply in an economy with a growing population? To make the individual's budget constraint identical to the resource constraint, it requires

$$\frac{v_{t+1}}{v_t} = \frac{n}{z} = n.$$

It means that $z = 1$. A constant money supply allows the economy to achieve the golden rule allocation.

- Why is $z = 1$ the optimal policy in an economy with a population growth? Some intuition:
  - Planner's resource constraint: if each young gives up 1 unit of consumption, the old can receive n units.
  - Individual's budget constraint: if the young gives up 1 unit of consumption, he will receive n/z units when old.
  - To convey the message that the economy can offer n units of goods to the old for each good not consumed by the young, the budget constraint has to be adjusted so that it coincides with the resource constraint.
- The value of money needs to increase at a rate n. That is $\frac{v_{t+1}}{v_t} = n$.

A Growing Money Supply: New Money to the Public

Summary

- So far, we have shown that when money supply grows at a rate z with $z > 1$, the allocation in a monetary equilibrium generally differs from the golden rule allocation.
- Inflation reduces individuals' incentives to hold money and adversely affects transactions using money. As a result, inflation may reduce output and welfare.
- In our model, the optimal growth rate of money supply is **always** $z = 1$, no matter the population is constant or growing. That is, **a constant money supply is the best policy**.
- Why might a government want to increase money supply?
  - The government may need to print money to finance its own expenditure.

A Growing Money Supply: New Money to Finance Government Purchases

A Monetary Equilibrium

- Government needs to create revenue to finance various types of expenditures. The use of money creation as a revenue device is called **"seigniorage"**.
- We focus on stationary allocations and a constant population.
- Suppose that money supply grows at a constant rate z: $M_t = zM_{t-1}$.

  - The amount of new money created in period t is

$$M_t - M_{t-1} = M_t - \frac{1}{z}M_t = \left(1 - \frac{1}{z}\right) M_t$$

  - The amount of goods that the government can purchase in period t is

$$G_t = v_t \left(M_t - M_{t-1}\right) = \left(1 - \frac{1}{z}\right) v_t M_t.$$

    This is also the government budget constraint.
  - Suppose that G_t does not affect an individual's consumption choice.

A Growing Money Supply: New Money to Finance Government Purchases

A Monetary Equilibrium

- An individual's budget constraint
  - first-period budget constraint

$$c_1 + v_t m_t \leq y;$$

  - second-period budget constraint

$$c_2 \leq v_{t+1} m_t;$$

  - lifetime budget constraint

$$c_1 + \frac{v_t}{v_{t+1}} c_2 \leq y.$$

- Notice that in this model, **individuals do not receive government transfers**.

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A Monetary Equilibrium

- Money's rate of return v_{t+1}/v_t:
  - value of money v_t is determined when money market clears

$$N(y - c_1) = v_t M_t \rightarrow v_t = \frac{N(y - c_1)}{M_t}.$$

  - money's rate of return

$$\frac{v_{t+1}}{v_t} = \frac{\frac{N(y-c_1)}{M_{t+1}}}{\frac{N(y-c_1)}{M_t}} = \frac{M_t}{M_{t+1}} = \frac{1}{z}$$

- We simplify the individual's budget constraint to

$$c_1 + zc_2 \leq y.$$

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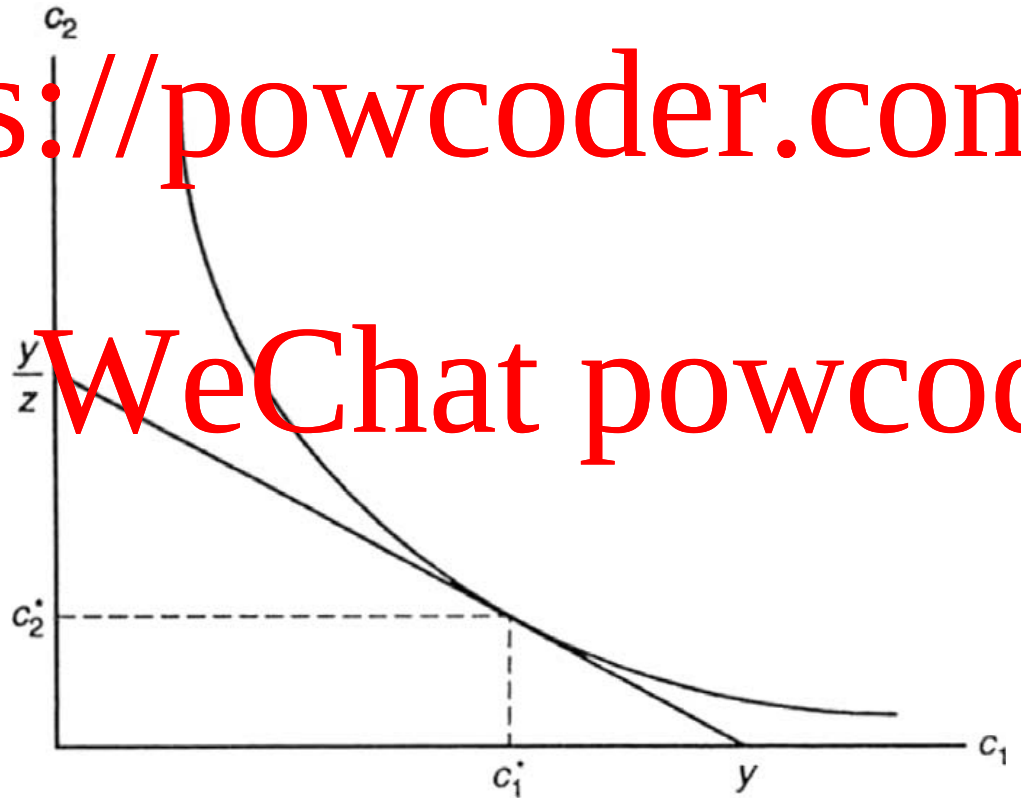
A Monetary Equilibrium

- Graphically, we depict the budget constraint and add a typical indifference curve.



- In a monetary equilibrium, the amount of goods that the government can purchase in period t can be found from

$$G_t = \left(1 - \frac{1}{z}\right) v_t M_t = \left(1 - \frac{1}{z}\right) N (y - c_1).$$

Notice that G_t is also stationary because $G_t = G_{t+1}$ for any t.

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Golden Rule Allocation

- To discuss the optimality of monetary equilibrium, we need to find the golden rule allocation.
- The planner's resource constraint

$$Nc_1 + Nc_2 + G \leq Ny,$$

where $G_t = G$ for stationary allocations. Divide both sides by N and let $g \equiv G/N$. The resource constraint can be rewritten as

$$c_1 + c_2 + g \leq y.$$

Notice that when the government uses new money to finance its own purchases, G or g is in the resource constraint. The government competes with individuals for resources.

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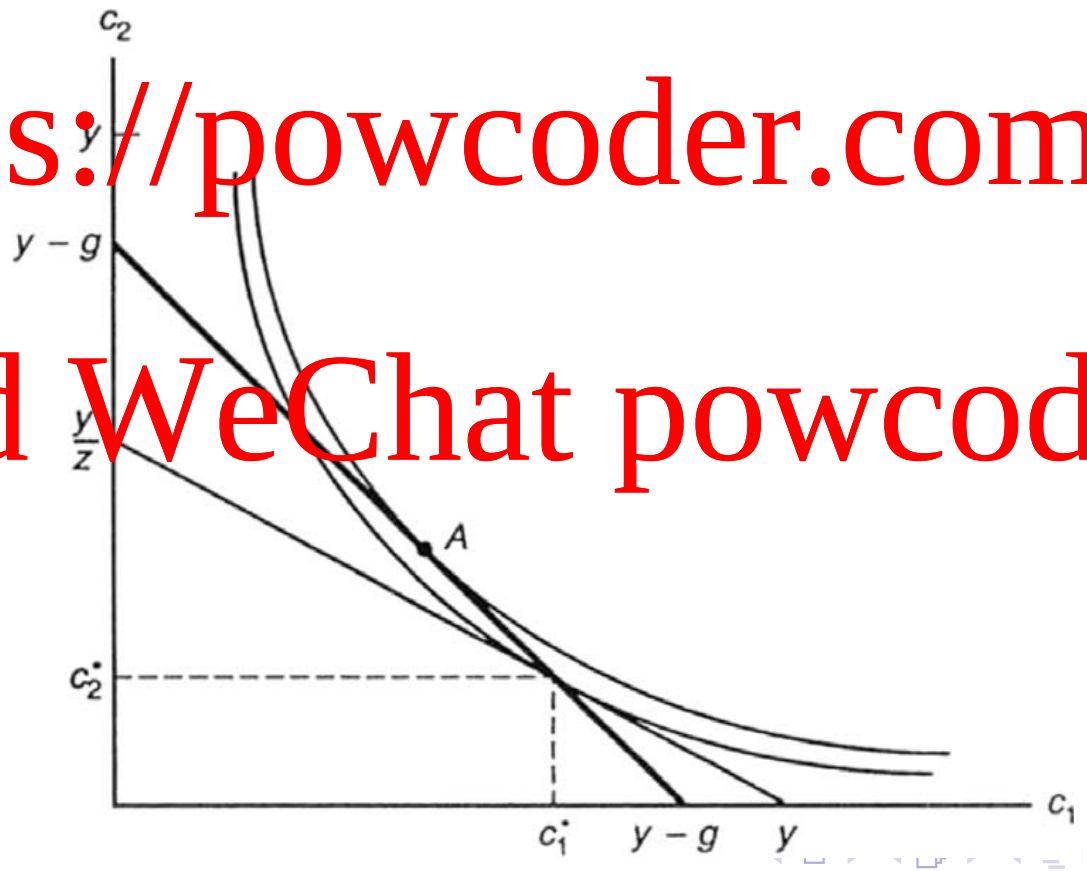
Golden Rule Allocation

- Graphically, we depict the resource constraint and add a typical indifference curve.



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Golden Rule Allocation

- We compare monetary equilibrium at point B with the golden rule allocation at point A.
- When the government prints new money to finance its own purchases, the allocation in a monetary equilibrium achieves a lower level of utility than the golden rule allocation.

- Inflation makes individuals trade less goods for money when young, which leads to
  - higher consumption when young;
  - lower consumption when old.

- Note that in comparison with the golden rule allocation, inflation hurts all future generations, as well as the initial old because c_2^* is lower in a monetary equilibrium.

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Inflation Tax v.s. Nondistorting Tax

- Creating new money is one way to finance government purchases $\rightarrow$ effectively an inflation tax. As we have shown, inflation leads to the monetary equilibrium allocation at point B, which is inferior to the golden rule allocation at point A.
- Given the need for the government to raise revenue, are there other ways to raise revenue and make the golden rule allocation attainable?
- Consider a **lump-sum tax**. Suppose that the government collects a fixed tax of τ goods from each old individual in every period.

A Growing Money Supply: New Money to Finance Government Purchases

Inflation Tax v.s. Nondistorting Tax

- Monetary equilibrium:
  - first- and second-period budget constraints

$$c_1 + v_t m_t \leq y \quad \text{and} \quad c_2 \leq v_{t+1} m_t - \tau$$

  - lifetime budget constraint

$$c_1 + \frac{v_t}{v_{t+1}} c_2 \leq y - \frac{v_t}{v_{t+1}} \tau.$$

- How can the government choose the values of v_{t+1}/v_t and τ so that
  - monetary equilibrium can be the same as the golden rule allocation;
  - the government can still finance its own purchases G?

A Growing Money Supply: New Money to Finance Government Purchases

Inflation Tax v.s. Nondistorting Tax

- The government can keep a constant money supply by imposing $\tau = g$. In this case, we can verify $v_{t+1}/v_t = 1$ and the individual's budget constraint becomes

$$c_1 + c_2 \leq y - g.$$

Now the budget constraint is identical to the planner's resource constraint. The allocation in a monetary equilibrium is the same as the golden rule allocation.

- Inflation tax (creating new money) and lump-sum taxes:
  - inflation tax: inferior equilibrium allocation but easy to implement – low cost
  - lump-sum taxes: golden rule allocation but hard to implement in reality.
- Money creation has been a popular means to raise government revenue.

A Growing Money Supply: New Money to Finance Government Purchases

Seigniorage: Theory and Evidence

- Recall, government revenue generated by money creation is called **seigniorage.**
- The use of seigniorage as a source of government revenue varies from country to country and from time to time.
  - For most developed countries during normal times: seigniorage contributes little to government revenue. For example, seigniorage in U.S. accounted for about 2% of total government revenue and for about 0.3% of gross national product from 1948 to 1989.
  - For countries that experience high inflation episodes like Argentina, Chile and etc., seigniorage contributes significantly to government revenue. For example, seigniorage accounted for about 46% of Argentinian government revenue and 6.2% of gross national product from 1960 to 1975.
  - An extreme case: Germany during its hyperinflation of the early 1920s. Seigniorage was about 10% to 15% of gross national product.

A Growing Money Supply: New Money to Finance Government Purchases

Seigniorage: Theory and Evidence

- Can the government simply print enough money to finance any purchase without the bother of direct taxation?
  - The government can print any amount of dollars.
  - The value of those dollars may shrink as the supply of money increases.
  - Seigniorage revenue in terms of real goods is limited by the real value of money.

- To formally examine how seigniorage revenue depends on the speed of money creation, we revisit the government budget constraint

$$G = (M_t - M_{t-1})\, v_t = \underbrace{\left(1 - \frac{1}{z}\right)}_{\text{tax rate}} \underbrace{v_t M_t}_{\text{tax base}} .$$

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Seigniorage: Theory and Evidence

- There are two terms in seigniorage revenue collected:
  - $1 - 1/z$: *tax rate* – the fraction of the real value of the money stock that becomes government revenue;
    - example: if $z = 1.05$, then $1 - 1/z = 1 - 1/1.05 = 0.0476$.
  - $v_t M_t$: *tax base* – the real value of the money stock (the value of the money stock in terms of goods).
- When the government increases the speed of printing money by raising z,
  - the tax rate $1 - 1/z$ will increase;
  - but what is the effect of z on the tax base $v_t M_t$?

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Seigniorage: Theory and Evidence

- Recall from the money market clearing condition

$$v_t M_t = N(y - c_1).$$

- We need to know how c_1 depends on z.

- Consider z^1 and z^2 where $z^2 > z^1$. How does c_1 respond to an increase in z from z^1 to z^2?
  - (c_1, c_2) in a monetary equilibrium is determined by the tangency point between the indifference curve and the budget constraint.
  - The budget constraint in this economy is

$$c_1 + zc_2 \leq y.$$

An increase in z would affect the individual's budget constraint.

- Graphically, when z increases from z^1 to z^2, c_1 increases from c_1^1 to c_1^2.

insert comparison

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Seigniorage: Theory and Evidence

- When z increases, the inflation rate increases. Higher inflation induces young to trade less goods for money so that c_1 increases and c_2 decreases.

- Now back to our money market clearing condition

$$v_t M_t = N(y - c_1).$$

When c_1 increases, the aggregate demand for money in real terms $N(y - c_1)$ decrease. Therefore, the aggregate supply of money in real terms $v_t M_t$ also decrease. The tax base $v_t M_t$ decreases.

- Economists have found evidence that higher inflation leads to lower real demand for money – see next slide.

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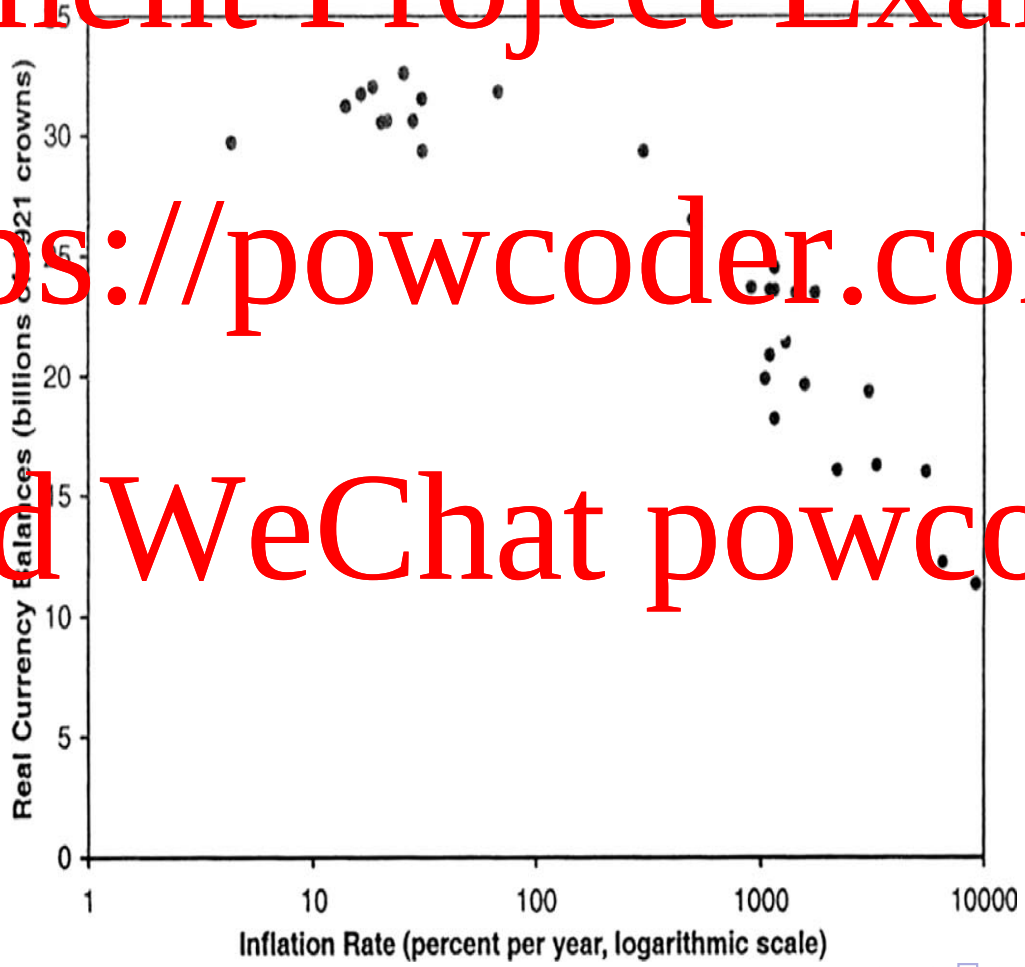
Seigniorage: Theory and Evidence

Real money balances during the Austrian hyperinflation



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Seigniorage: Theory and Evidence

- So far, we have found that when growth rate of money supply z increases,
  - the tax rate $1 - 1/z$ increases;
  - the tax base $v_t M_t$ decreases;

- Overall, seigniorage revenue

$$\left(1 - \frac{1}{z}\right) v_t M = \left(1 - \frac{1}{z}\right) N (y - c_1),$$

may or may not increase as z increases. The exact relationship between the seigniorage revenue and the growth rate of money supply z depends on the utility function of individuals and anything else that affects the demand for money.

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Seigniorage: Theory and Evidence

- The general shape of seigniorage revenue as a function of z **resembles** the Laffer curve:
  - at low growth rates of money supply, a higher growth rate leads to a higher level of seigniorage;
  - at high growth rates of money supply, a higher growth rate leads to a lower level of seigniorage;
  - there exists a growth rate of money supply that maximizes seigniorage.
- The original Laffer curve describes the relationship between income tax rate and income tax revenue.

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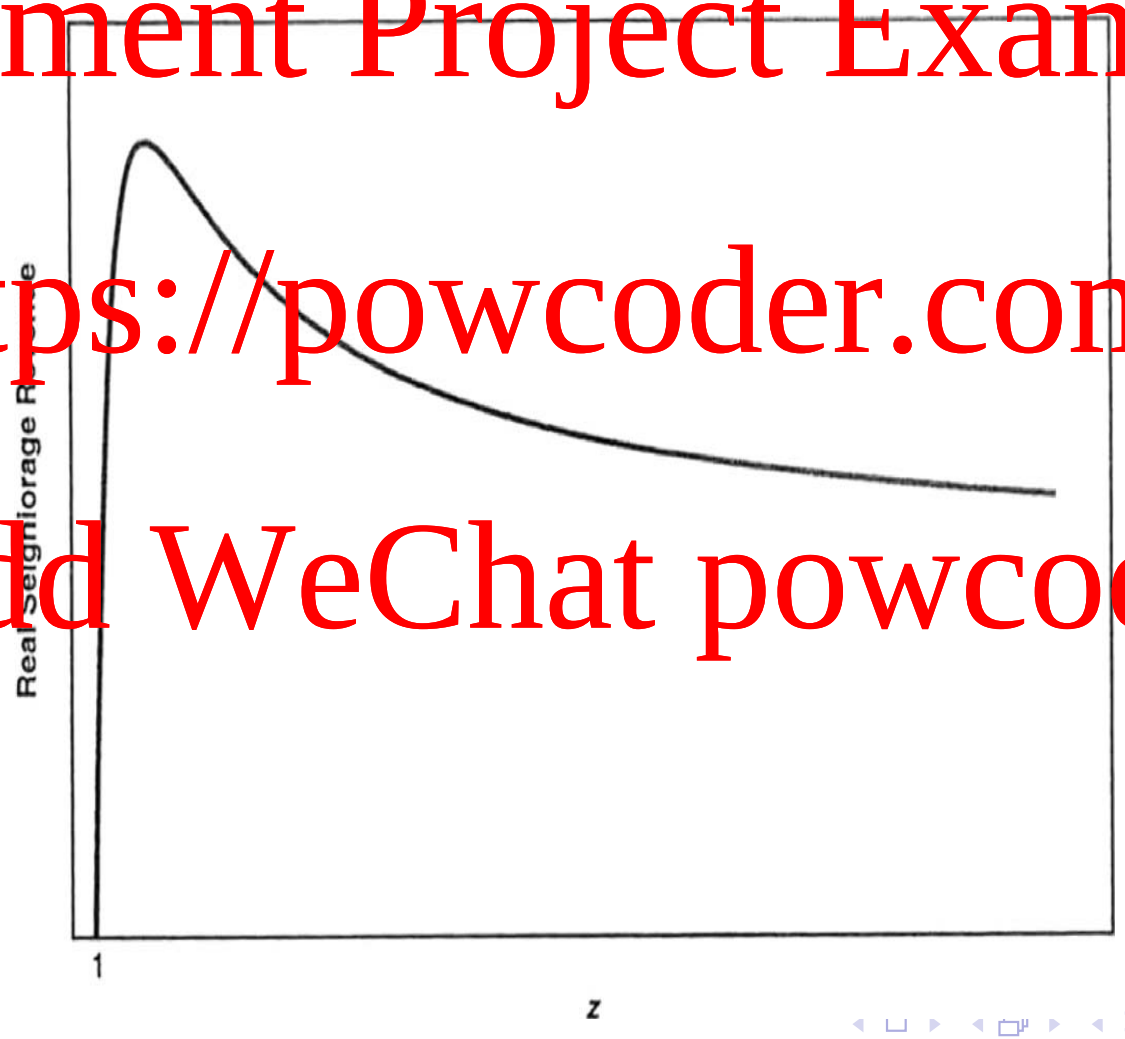
Seigniorage: Theory and Evidence



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Seigniorage: Theory and Evidence

Seigniorage revenue during the Austrian hyperinflation