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# Inflation and innovation with a cash-in-advance constraint on human capital accumulation

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## HIGHLIGHTS

- We study the growth and welfare effects of monetary policy.
- We incorporate a cash-in-advance (CIA) constraint on human capital accumulation (HCA).
- An increase in the nominal interest rate decreases HCA and thereby growth and welfare.
- Long-run growth increases 0.61% by reducing the nominal interest rate from 9.9% to 0%.
- The welfare gain is equivalent to a permanent increase in consumption of 15.98%.

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ABSTRACT

This note explores a novel channel – a cash-in-advance (CIA) constraint on endogenous human capital investment – through which monetary policy impacts growth and welfare in a scale-invariant Schumpeterian growth model. We find the following. An increase in the nominal interest rate leads to a decrease in human capital investment, which in turn reduces long-run growth and welfare. Calibration shows that long-run growth increases 0.61% by reducing the nominal interest rate from 9.9% (the sample mean of the U.S.) to 0%. The corresponding welfare gain is equivalent to a permanent increase in consumption of 15.98%. The growth and welfare effects depend on the strength of the CIA constraint on human capital investment. Our study has strong policy implications for developing countries where out-of-pocket money may be important for schooling.



## 1. Introduction

A large body of literature exists on the role of human capital in the process of economic development (see elaboration below). In this paper, we contribute by analyzing a relevant case in which there exists a cash-in-advance (CIA) constraint on human capital accumulation (HCA) in a Schumpeterian growth model, based on Chu et al. (2017b). In so doing, we reveal an important channel for monetary policy to impact economic growth and welfare. We find the following. An increase in the nominal interest rate leads to a decrease in human capital investment, which in turn reduces long-run growth and welfare.

HCA has been argued to be an important determinant of long-run growth (e.g., Uzawa, 1965; Lucas, 1988, 2015; Glaeser et al., 2004). The recent R&D-based Schumpeterian growth models have shown HCA as a twin-engine of long-run growth (see e.g., Chu et al., 2013, 2017b).[2]

Researchers have provided evidence that HCA is subject to borrowing constraints (e.g., Belley and Lochner, 2007; Lochner and Monge-Naranjo, 2012; Hai and Heckman, 2017, and references therein). Therefore, it is meaningful to investigate the growth and welfare effects of inflation when HCA is subject to the CIA

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[2] The other engine is R&D induced technological progress.

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constraint. Specifically, we introduce money via a CIA constraint on HCA into a scale-invariant Schumpeterian growth model. We find the following. All else being equal, a higher nominal interest rate and thereby a higher inflation rate via the CIA constraint on HCA makes consumption cheaper relative to human capital investment, thus decreasing human capital investment. The decrease in human capital investment decreases the amount of effective labor supplied to production and R&D, leading to a decrease in long-run growth and social welfare.

We calibrate the model to estimate the growth and welfare effects of a change in the nominal interest rate. We find that long-run growth increases 0.61% by reducing the nominal interest rate from 9.9% (the sample mean, elaborated below) to 0%. The corresponding welfare gain is equivalent to a permanent increase in consumption of 15.98%. As a counterfactual, we find that the growth and welfare effects significantly depend on the strength of the CIA constraint on HCA. In particular, without the CIA constraint on HCA (i.e., the CIA constraint applies only on R&D), by reducing the nominal interest rate from 9.9% to 0%, the growth gain is 0.06% annually, and the welfare gain is equivalent to a permanent increase in consumption of 1.07%. Therefore, without the CIA constraint on HCA, the growth and welfare effects are much smaller when the nominal interest rate increases.

This study relates to the literature on inflation and economic growth (see e.g., Dotsey and Sarte, 2000; Chu and Lai, 2013; Chu and Cozzi, 2014; Chu et al., 2015; Huang et al., 2015; He and Zou, 2016; Chu et al., 2017a, 2018; He, 2018a, b). Our study has strong policy implications for developing countries where out-of-pocket money may be important for schooling. The government may find it growth and welfare enhancing to subsidize human capital investment.

## 2. Monetary Schumpeterian model

Built on existing Schumpeterian growth models (e.g., Chu and Cozzi, 2014), we model money with a CIA constraint on R&D expenditure.

### 2.1. Households

At time $t$, the population size of each household is fixed at 1. There is a unit continuum of identical households, which have a lifetime utility function as

$$U = \int_0^{\infty} e^{-\rho t} \ln (c_t)\, dt, \tag{1}$$

where $c_t$ is per capita real consumption of final goods (numeraire) at time $t$. $\rho > 0$ is the rate of time preference. For simplicity, we assume inelastic labor supply.

Each household maximizes its lifetime utility given in Eq. (1), subject to the asset-accumulation equation given by

$$\dot{a}_t + \dot{m}_t = r_t a_t + w_t h_t - c_t - t_t - \pi_t m_t + i_t b_t + \tau_t, \tag{2}$$

where $a_t$ is the real value of equity shares in monopolistic intermediate goods firms owned by each member of households; $r_t$ and $w_t$ are the rate of real interest and wage rate, respectively; and $h_t$ is effective labor supply in production and R&D. Here we follow Chu et al. (2013) to assume that total labor supply equals the product of time endowment 1 and human capital $h_t$. $c_t$ is per capita consumption. $t_t$ is per capita spending in education (including tuition fee and other expenses on education). $m_t$ is the real money balance held by each person, and $\pi_t$ is the cost of holding money (i.e., the inflation rate). In Eq. (2), each person also receives a per capita lump-sum transfer of the seigniorage revenue $\tau_t$ from the government (or pay a lump-sum tax if $\tau_t < 0$).

The CIA constraint is given by

$$b_t + \theta t_t \le m_t, \tag{3}$$

where $b_t$ is the amount of money borrowed by entrepreneurs to finance R&D, and the rate of return is $i_t$ (i.e., the nominal interest rate); $\theta \in [0, 1]$ captures the strength of the CIA constraint on human capital investment. $\theta = 0$ means that the human capital investment is not subject to the CIA constraint.

We assume that human capital needs only monetary or material spending (i.e., $t_t$) to produce. For the sake of simplicity (and to avoid multiple equilibria as in Chu et al., 2017b), we assume that human capital does not need time to produce (see Chu et al., 2017b, for a study that assumes human capital needs only time to produce). The accumulation equation of human capital $h_t$ is given by

$$\dot{h}_t = \xi \frac{t_t}{w_t}, \tag{4}$$

where $\xi$ is the productivity parameter for human capital investment. Eq. (4) shows that the accumulation of $h_t$ is increasing in the effective amount of education expenditure $t_t$ over the wage rate $w_t$. This assumption is made to ensure that the balanced growth rate is a constant, as observed in advanced economies. To see this, we can rewrite (4) as $\dot{h}_t / h_t = \xi \frac{t_t}{w_t h_t}$, which shows that the growth rate of human capital is linear in the effective amount of education expenditure $t_t$ over the market value of human capital $w_t h_t$. We can deem $t_t/(w_t h_t)$ as effective per human capital educational spending. Without scaling by the wage rate, the growth rate of human capital will keep increasing over time, which is inconsistent with the observed constant long-run growth in advanced countries.

We can derive the no-arbitrage condition (i.e., the Fisher equation) $i_t = \pi_t + r_t$ (we omit the derivation to save space, but it is available upon request). The optimality condition for consumption is

$$\frac{1}{c_t} = \mu_t, \tag{5}$$

where $\mu_t$ the Hamiltonian co-state variable on Eq. (2). The intertemporal optimality condition is

$$-\frac{\dot{\mu}_t}{\mu_t} = r_t - \rho. \tag{6}$$

We also have the arbitrage condition between investment in asset holding and that in human capital:

$$r_t = \frac{\dot{w}_t}{w_t} + \frac{\xi}{(1 + \theta i_t)}. \tag{7}$$

### 2.2. Final-goods sector

The final goods sector is competitive. The production function of the final goods firms is given by

$$y_t = \exp\left( \int_0^1 \ln x_t(j)\, dj \right), \tag{8}$$

where $x_t(j)$ denotes intermediate goods $j \in [0, 1]$. The final goods firms maximize their profit, taking the price of each intermediate good $j$, denoted $p_t(j)$, as given. The demand function for $x_t(j)$ is

$$x_t(j) = y_t / p_t(j). \tag{9}$$