



# Capital accumulation, sectoral heterogeneity and the Taylor principle



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## ABSTRACT

In the presence of capital accumulation the Taylor principle may not be sufficient for determinacy under reasonable parameter values. In this paper I consider a two-sector extension of the models used in the existing literature. I show that what matters for whether the Taylor principle is sufficient is the price stickiness of investment goods. Price stickiness of consumer goods on the other hand matters very little. The Taylor principle is sufficient, I find, unless there is considerable price stickiness in the investment-goods sector.

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## 1. Introduction

The celebrated Taylor principle posits that a central bank should adjust the nominal interest rate by more than one for one in response to changes in inflation. In many New Keynesian (NK) models this is a sufficient condition for determinacy, i.e. local uniqueness of rational expectations equilibrium.

Carlstrom and Fuerst (2005) and Sveen and Weinke (2005) show that the Taylor principle is often insufficient to insure determinacy in models with endogenous capital accumulation. Specifically, Carlstrom and Fuerst (2005) demonstrate that responding to expected as opposed to current inflation almost always generates indeterminacy. The intuition is simple. Current investment tends to reduce future inflation since labor productivity increases when the additional capital stock becomes productive. Therefore, the central bank might respond to an investment boom that is unrelated to economic fundamentals by decreasing nominal interest rates and thereby rationalizing the boom ex post. Sveen and Weinke (2005) show that the Taylor principle may not be sufficient even if the central bank reacts to current inflation and that this is more likely if price setters are sufficiently forward-looking.<sup>1</sup>

The goal of the present paper is to analyze the effect of sectoral heterogeneity on the determinacy properties of the model. To this end I extend the model in Sveen and Weinke (2007) to allow for two sectors. The first sector produces consumer goods while the second produces investment goods. In both sectors, monopolistically competitive firms produce differentiated goods using capital and labor, where capital is accumulated at the firm level, while labor is free to move between sectors. The earlier literature generally assumes that there is only one sector and that goods can be used for both

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<sup>1</sup> Many papers have followed up on the implications of endogenous capital accumulation for indeterminacy. See Huang and Meng (2007), Sveen and Weinke (2007, 2013), Kurozumi and Van Zandweghe (2008), and Duffy and Xiao (2011).

consumption and investment. I show that this assumption is crucial for some of the main results obtained in the existing literature. More precisely, I show that what matters for determinacy is price stickiness in the investment-goods sector, while price stickiness in the consumer-goods sector matters very little. In fact, I find the Taylor principle to be sufficient for determinacy unless there is considerable price stickiness in the investment-goods sector. I also find that, with reasonable heterogeneity in price rigidity and capital intensity, realistic responses to expected inflation in the interest rate rule may generate determinacy. This provides an important qualification of the abovementioned result for forward-looking rules.

The main motivation for extending the model to include two sectors is the research on the source of business cycles over the past decade. In that literature, investment-specific disturbances have emerged as a potentially viable alternative to the innovations in total factor productivity (see, e.g., Schmitt-Grohé and Uribe, 2011b). Using a structural VAR, Fisher (2006) argues that those disturbances could be very important for understanding business cycle fluctuations.<sup>2</sup> An important implication of this line of research is that the relative price of investment to consumption goods is an endogenous variable with important cyclical behavior. As I show below, the endogenous response of this relative price is also a key to understanding the main findings of the current paper.

Another strand of the literature takes as its starting point the abundant empirical evidence that price stickiness differs considerably across different sectors of the economy (see, e.g., Bils and Klenow, 2004; Nakamura and Steinsson, 2008a). For example, Carvalho (2006) analyzes real effects of a monetary policy shock in a model with sectoral heterogeneity in price stickiness. He finds that this makes aggregate prices react less and real variables react more compared to a one-sector model.<sup>3</sup> Carlstrom et al. (2006) analyze indeterminacy in a two-sector model with heterogeneity in price stickiness and immobile labor and show that a modified Taylor principle holds in that environment. Importantly, if the central bank targets inflation in one sector and responds with a coefficient larger than unity to inflation in that sector, this policy will ensure determinacy in all sectors. Interestingly, the key assumption behind this result is again the behavior of a relative price. More precisely, since agents react to changes in relative prices, those prices will always be determinate. When the central bank reacts to some inflation rate obeying the Taylor principle, the determinacy of the relative prices will ensure aggregate determinacy.

The remainder of the paper is organized as follows. Section 2 outlines the model structure, including the resulting linearized equilibrium conditions. The results are presented in Section 3 and Section 4 concludes.

## 2. The model

The model features two sectors with monopolistic competition. In both sectors there is a continuum of firms producing differentiated goods. Firms hire labor, set prices à la Calvo (1983), and invest. I assume two restrictions on capital accumulation. First, the additional capital becomes productive with a one period delay and, second, there is a convex capital adjustment cost. There is a common labor market across the two sectors, but below I also allow for sector-specific labor markets. Period utility is assumed to be separable in its two arguments: leisure and consumption. I follow Erceg et al. (2000) and assume that each household member is the monopolistically competitive supplier of a differentiated type of labor and nominal wages are set in a staggered manner. The details of the model are found in the Appendix and I turn directly to the resulting linearized equilibrium conditions.<sup>4</sup> All variables are expressed in terms of log-deviations from their steady state values except for wage and price inflation and interest rates, which are expressed in levels. I restrict attention to a linear approximation around a zero inflation steady state.

### 2.1. Some linearized equilibrium conditions

The consumption Euler equation reads

$$c_t = E_t c_{t+1} + (r_t - E_t \pi_{c,t+1} - \rho), \quad (1)$$

where  $c_t$  denotes aggregate consumption, and  $r_t$  and  $\pi_{c,t}$  are the nominal interest rate and the CPI inflation rate, respectively. Moreover,  $E_t$  is used to denote the expectational operator conditional on time  $t$  information. Parameter  $\rho \equiv -\log \beta$  is the time discount rate and  $\beta$  denotes the household's subjective discount factor.

Nominal wage inflation,  $\omega_t$ , is obtained from averaging and aggregating optimal wage-setting decisions. It is given by

$$\omega_t = \beta E_t \omega_{t+1} + \kappa_w [mrs_t - w_t] \quad (2)$$

where I have used the definition

$$\kappa_w \equiv \frac{(1 - \beta \theta_w)(1 - \theta_w)}{\theta_w} \frac{1}{1 + \eta \varepsilon_N},$$

<sup>2</sup> Greenwood et al. (1997) were the first to point out the potential role of investment-specific technological change for long-run growth. Several papers have followed up on the issue of investment specific shocks, see, e.g., Justiniano et al. (2010, 2011) and Schmitt-Grohé and Uribe (2011a).

<sup>3</sup> Bouakez et al. (2009) construct and estimate a multisector sticky price model and argue that their model amplifies the propagation mechanism compared to a symmetric counterpart and delivers additional persistence in response to monetary disturbances.

<sup>4</sup> See also Justiniano et al. (2011) for a less articulated version of the same set-up, without wage stickiness and capital adjustment costs. They show that the relative price of investment goods in general is different from the investment-specific technology factor.

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