



# Public health spending, old-age productivity and economic growth: Chaotic cycles under perfect foresight

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## ABSTRACT

This paper analyses the dynamics of a double Cobb–Douglas economy with overlapping generations and public health investments that affect the supply of efficient labour of the old-aged. It is shown that the positive steady state of the economy is unique. Moreover, we provide necessary and sufficient conditions for the emergence of endogenous deterministic complex cycles when individuals are perfectly foresighted. Interestingly, (i) the equilibrium dynamics shows rather complicated phenomena such as a multiplicity of bubblings depending on the size of the public health system, and (ii) the higher the degree of thriftiness, the likelier an economy is exposed to endogenous fluctuations because the need to save when young to support consumption when old is reduced.

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## 1. Introduction

The macroeconomic literature has devoted a long lasting attention to the understanding of the fundamental causes that generate fluctuations in the economic activity (i.e., business cycles). Starting from the Keynesian tradition, business cycles are generated from changes in aggregate demand conditions through the sluggish adjustment of prices and wages (e.g., Hicks, 1937). While such a strand of literature was focused on short-run issues in explaining cycle, the emergence of the real business cycle literature (e.g., Long and Plosser, 1983), which aims to explain the existence of cycles in macroeconomic variables through the propagation of temporary fundamental shocks within the neoclassical growth model, has renewed the interest in long-run economic growth and fluctuations. However, such a literature is grounded on a stochastic origin of economic cycles.

Unlike this, another strand of literature argue that exogenous shocks are not necessary for the emergence of fluctuations. Indeed, non-monotonicities in the dynamic behaviour of economic variables can generate periodic as well as aperiodic, but deterministic, orbits that resemble random ones (e.g., Goodwin, 1967; Grandmont, 1985; Farmer, 1986; Reichlin, 1986; de Vilder, 1996). While the first author explains the occurrence of growth and cycles in a Marxian labour market context, which has been criticised for the lacking of sound micro-foundations, the other three ones find that business cycles can occur

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in the neoclassical overlapping generation (OLG) model with rational individuals, showing that endogenous deterministic, rather than exogenous stochastic, fluctuations can also be generated in orthodox models. However, in the neoclassical OLG growth model with production à la Diamond (1965) regular and complex cycles can emerge only either assuming not fully rational individuals, i.e. with either myopic or adaptive expectations about future factor prices (Benhabib and Day, 1982; Michel and de la Croix, 2000; de la Croix and Michel, 2002), or extending it with the assumptions of, e.g., endogenous labour supply (Medio and Negroni, 1996), production externality (Cazzavillan, 1996), market imperfections (Aloi et al., 2000), PAYG pensions depending on previous earnings (Wagener, 2003), or taking the accumulation of government debt into consideration (Yokoo, 2000), which result in higher dimensional systems than the one-dimensional Diamond's model and thus able to describe more complicated dynamical events such as the Neimark–Sacker bifurcations.<sup>2</sup> In fact, the economic literature has definitely shown, by resorting to various mathematical tools, that the Diamond's model with rational individuals (perfect foresight) can never possess an unstable equilibrium, so that business cycle is prevented in such a case (Galor and Ryder, 1989; Longo and Valori, 2001; Wendner, 2003; Chen et al., 2008). Therefore, extending the basic OLG growth model with production with hypotheses that, however, preserve the feature of the one-dimensional map, may hardly transform it in a model suited to explain fluctuations in macroeconomic variables if individuals are rational. An exception, however, is Bhattacharya and Qiao (2007) who assume individual lifetime as being dependent of the health status which is, in turn, augmented by private health investments accompanied by a complementary tax-financed public health program, and show that the economy may be exposed to aggregate endogenous fluctuations and even chaotic motions. However, and most important, in their model not only endogenous fluctuations can occur when the private and public inputs in the longevity function are fairly complementary, but savings are also independent from the future interest rate and, hence, the hypothesis of perfect foresight of agents is irrelevant.

As regard the health of people, an evident and important stylised fact is the widespread rise in health spending, which is mainly public provided in several countries in the world, especially in Europe. In fact, as noted by Leung and Wang (2010, p. 11) “With few exceptions, we have observed consistent and steady rises over time of health-care expenditure, both in absolute terms and as percentages of GDP, in almost all countries in the world. The total health-care expenditures among European Economic Monetary Union countries, for example, reached an average 9% of GDP in the 1990s”.

This paper aims to investigate the properties of the equilibrium dynamics in the two-period Diamond's (1965) OLG growth model under two slight assumptions: (i) individuals work not only when young but also in the second period of life in a measure tuned by an efficiency parameter, as in de la Croix and Michel (2007); (ii) the supply of efficient labour of the old-aged, whose value results from a combined effect of age experience, sick days, retirement time, disabilities and so on, depends on the individual health status,<sup>3</sup> which is, in turn, augmented by public investments on health. In particular, following a recent literature (Blackburn and Cipriani, 2002; de la Croix and Ponthiere, 2010), it is assumed that such an expenditure is transformed into better health according to a S-shaped relationship to capture the idea that health spending may have a more intense effect in promoting health only when a certain threshold is achieved (e.g., vaccine and immunization programmes) while becoming scarcely effective when the health status is close to its saturating value.

Our main results are the following. First, we characterise the “bi-modal” shape of the phase map and show the existence and uniqueness of the positive equilibrium. Second, we analyse the local dynamics of the system and consider local stability and the emergence of a local bifurcation. We find necessary and sufficient conditions for the existence of oscillations around the steady state as well as necessary and sufficient conditions for such an equilibrium to be non-stationary. Moreover, numerical simulations also reveal that for intermediate-sized provision of tax-financed health services, chaotic cycles emerge and, in particular, multiple bubbling phenomena (see the discussion in Section 4 for details) can occur. We find that endogenous fluctuations are likelier if the degree of thriftiness is fairly high, i.e. when individuals prefer to smooth consumption over their second period of life. The equilibrium dynamics in our model therefore may be cyclical, and most important, regular and chaotic business cycles appear to be the rule rather than the exception, while also showing a strong complexity.

This paper contributes to two strands of literature centred on the issues of: (i) endogenous, as an alternative to stochastically driven, business cycles, and (ii) endogenous lifetime. The value added of the paper is twofold. First, it is shown that deterministic chaos<sup>4</sup> is generated in a model in which it is generally prevented.<sup>5</sup> Second, while the effects of the introduction of endogenous health as the main determinant of the individual life span have recently been investigated assuming either

<sup>2</sup> Note that even in higher dimensional systems the emergence of business cycles in OLG models with perfectly foresighted individuals is an exception rather than the rule. For instance, the modified OLG model by Lines (2001), where the assumption that retirees are not endowed with the entire capital stock results in a two-dimensional system, is able to describe the initial phase of accumulation but unable to generate any type of cycles. For a survey on chaotic dynamics in economics see Rosser (1999).

<sup>3</sup> The link between health status and labour productivity has been early recognised by the pioneering Grossman (1972) who argues that: “. . . the level of ill-health measured by the rates of mortality and morbidity, influences the amount and productivity of labour supplied to an economy” (p. xiii). Moreover, some recent empirical works have found that health status is an important determinant of labour participation, especially for older workers (see, e.g., Cai, 2010; García-Gómez et al., 2010).

<sup>4</sup> This result is of interest because it shows that the equilibrium dynamics may generate business cycles without the need of any exogenous shock. In fact, as Bhattacharya and Qiao (2007, p. 2528) claimed: “These fluctuations are interesting to economists because they represent stylized business cycles that are generated purely from within an economic system and not from exogenous stochastic shocks.”

<sup>5</sup> We recall that in the absence of our two main assumptions, the equilibrium dynamics in the model would be globally stable.

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