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Urban sprawl occurrence under spatially varying agricultural amenities ☆

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ABSTRACT

This paper presents a spatially explicit model to examine the importance of agricultural amenities as a determinant of the urban and suburban spatial structures. By introducing endogenous agricultural amenities into the classical monocentric model, we provide an intuitive explanation of leapfrog development. We show how urban development patterns highly depend on the intensity of surrounding farms and their ability to produce amenities. We also show that, even in the absence of a particular landscape feature or any exogenous source of amenities, fragmented urban sprawl is a natural development pattern for a city surrounded by a spatially varying agricultural environment.

1. Introduction

Although its importance first became apparent in the second half of the 20th century, urban sprawl is still considered to be a major problem today. It refers to the spreading outwards of a city to its outskirts that is excessively relative to what is socially desirable. Most observers seem to agree that fragmentation of housing with low-density is the most significant feature of urban sprawl. Fragmented areas can take two forms: first, they are connected to the city taking the form of contiguous urban extension. Second, they can be relatively far from urban areas, reflected by a discontinuous urban area, so-called leapfrog development (EEA, 2006; Irwin and Bockstael, 2007).

Numerous studies have revealed the nature of urban sprawl and the reasons for its occurrence in different contexts (Anas et al., 1998; Brueckner, 2000; Brueckner et al., 2001; Glaeser et al., 2004; Nechyba and Walsh, 2004; Burchfield et al., 2006; Patacchini and Zenou, 2009). The role of physical geography, the rise in household incomes, population growth and the decline in the cost of commuting are often identified as the fundamental forces that have led to sprawl. However, other factors play a major role in shaping the urban structure. Farming in vicinity of cities is one of these factors. Indeed, in recent years, most sprawl in the United States or Europe has occurred on agricultural land. In the US, about 30% of farms are located in metropolitan areas (Gardner, 1994). The US Census bureau[1] estimates that in 2010, 71.2% of the US population lived in Urbanised Areas (UAs). In France, 44% of French farms are located in so-called periurban areas (Agreste, 2002) and the population in periurban and immediate suburban areas is estimated at more than 30 million (Baccaïni and Sémécurbe, 2009), nearly a half of the total French population. Note that these data depend on the relative definition given to urban and periurban areas. However, it is

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[1] http://www.census.gov/geo/reference/ua/urban-rural-2010.html (last visit: July 5th 2013)

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clear that these areas of residential expansion represent a substantial share of the population and farms in the US and in Europe. Studying and understanding the relationships between residential development and agricultural activity are therefore of high interest to planners and policy makers. While planning and zoning policies play an important role in controlling the conversion of agricultural land, the general trend is for the large majority of urbanised land to have been converted from agricultural uses (Greene and Stager, 2001; Walker, 2001; EEA, 2006; Livanis et al., 2006). It is also recognized that agricultural amenities in suburban areas have a strong pull effect on household location decisions and may encourage the development of areas occupied by both farmers and commuting households (Roe et al., 2004; Cavailhès et al., 2004; Ready and Abdalla, 2005). Despite these observations, few studies have been undertaken on the role of farming in the ongoing decentralization of urban areas.

The purpose of this paper is to investigate the interaction between agriculture and urban sprawl. We present a spatially explicit model which highlights the role of agriculture in determining suburban spatial structure.

Many prior studies examine the influence of amenities on urban development, but a few explicitly consider the spatial effects of agricultural amenities. The most widely used theoretical structure in the related literature is the monocentric city model, derived from the pioneering contributions of Alonso, (1964), Muth (1969), Mills (1972) and Wheaton (1974).[2] In this model, areas close to the central business district (CBD) have higher land prices and greater housing density. These areas are more desirable because of lower commuting costs. One important assumption of this model is to consider that urban development occurs on a featureless plain. Under this assumption, only the expectation behaviour of owners can explain the existence of scattered urban areas. This mechanism has been the subject of several papers on sprawl (Mills, 1981; Wheaton, 1982; Titman, 1985; Capozza and Helsley, 1989).

Polinsky and Shavell (1976) gave up the hypothesis of uniform landscape and introduced an environmental amenity characterised by its distance to the CBD. They show how the amenity changes the spatial pattern of the city. In the same vein, to explain the fact that in some cities poorer people live near the city centre, while the rich live on the periphery, Brueckner et al. (1999) expand the monocentric city model to include amenities, characterised by distance to the CBD. In these two studies, amenities do not occupy space. In contrast, Mills (1981), Nelson (1985) and Lee and Fujita (1997) analyse the effects of "greenbelts" that form a ring of open space around a city. In all these studies, amenities are spatially homogenous.

Otherwise, spatially heterogeneous amenities have also been used as a possible reason for the fragmentation of urban space. This is due to the fact that the household bid-function is not necessarily monotonous with regards to the distance from the CBD (Ogawa and Fujita, 1980; Yang and Fujita, 1983; Fujita and Kashiwadani, 1989). Several recent papers develop two-dimensional urban models including environmental amenities that show the effect of the location, size and shape of open space on spatial equilibrium in a monocentric city model (Wu and Plantinga, 2003; Turner, 2005; Wu, 2006; Kovacs and Larson, 2007; Tajibaeva et al., 2008; Newburn and Berck, 2011). These studies provide a more intuitive explanation for leapfrog development than previous studies, but still treat agricultural rent and amenities as exogenous.

Overall, monocentric city models exploring the possibilities of leapfrog development assume an exogenous agricultural rent to define the city boundary. By doing so, these studies are not able to explain entirely the interactions between agriculture and cities. Thus, farm structures have no effect on agricultural land conversion. However, there are some studies that explicitly consider the movement of city limits in relation to an agricultural hinterland lying beyond the city (Muth, 1961; Walker, 2001; Cavailhès et al., 2004). These studies borrow ideas from the monocentric-city model and the spatial agricultural model developed by von Thünen. They were not specifically concerned with urban sprawl, but offer an interesting analytical framework for better understanding the interactions between the city and agriculture.

Although urban sprawl is a dynamic and irreversible process, it has been revealed that the static monocentric model is empirically robust with today's cities (McGrath, 2005). Our model builds on Wu and Plantinga (2003), Wu (2006) and Cavailhès et al. (2004). Contrary to Wu and Plantinga (2003) and Wu (2006), we model the behaviour of farmers *à la* von Thünen. Small and intensive farms are located close to the city boundary while larger, more extensive farms are further away. This can be explained by the urban pressure on agricultural land prices. Far away from the city boundary, land becomes less expensive and may be substituted to capital. This may occur within a few miles for small cities, and up to ten miles away for larger settlements. For instance, Cavailhès and Wavresky (2007) show that in medium-sized French urban areas (between 20,000 and 50,000 inhabitants), agricultural land prices decrease from 5500 €/ha close to the city centre, to 4500 €/ha 5 km away, and down to 1500 €/ha 20 km away. More interestingly for what follows in the paper, they also observe that for identical kinds of crops, management techniques are more intensive[3] near cities than further away.

We emphasize the role of agricultural amenities, as a joint-product of farming, in household welfare. In Cavailhès et al. (2004) amenities are proportional to agricultural land. Thus, intensive farms produce the same level of amenities as extensive ones. This assumption is simply at odds with reality. We observe most often a certain spatial heterogeneity of agricultural amenities which depends on the intensity of agriculture. This variability of agricultural practices may be strong enough to influence residential development patterns. Indeed, several empirical studies show how the implementation of a public policy aimed at preserving traditional landscapes or promoting the provision of positive externalities may induce suburban development in surrounding areas (Roe et al., 2004; Irwin and Bockstael, 2004; Towe, 2010; Geniaux and Napoléone, 2011). Thus, contrary to Cavailhès et al. (2004), we assume that the level of amenity is defined at each point in space according to the level of agricultural intensity. So, within the farming area under the influence of the city, intensive farms produce fewer amenities than extensive ones. This expansion allows us to consider a richer set of situations on urban sprawl and the spatial configurations of agriculture. More particularly, we explain the occurrence of fragmented patterns of residential development by the spatial heterogeneity of agriculture. By providing higher level of environmental amenities, more extensive farmers may encourage households to settle further away from the city in spite of additional commuting costs.

We therefore develop a theoretical framework which enables us to reproduce rich spatial configurations, in particular endogenous fragmented development.

The remainder of the paper is organised as follows. In Section 2, we present the model and discuss the conditions for spatial equilibrium and more particularly for leapfrog development. Section 3 gives a numerical illustration of the main results of the model, while Section 4 concludes the paper.

2. The model

2.1. Structure of the city

In order to study urban development patterns in the presence of spatially varying agriculture, we develop a static model of a monocentric open-city. Space is represented by the real line $X = (-\infty,+\infty)$ with a CBD at its origin. It is assumed that all non-agricultural employment is

[2] A good synthesis is provided by Fujita (1989).

[3] Intensities of crops management techniques are measured through the standard gross margin per hectare, annual working units per hectare and the motorized power per hectare.