Agricultural Productivity and Urbanization: A Smooth Coefficient Regression Analysis

Xiaofei Li[1], Raymond J.G.M. Florax[2,3], and Brigitte S. Waldorf[4]

[1] *Department of Agricultural Economics, Purdue University, USA*
li597@purdue.edu
[2] *Department of Agricultural Economics, Purdue University, USA*
[3] *Department of Spatial Economics, VU University Amsterdam, The Netherlands*
rflorax@purdue.edu
[4] *Department of Agricultural Economics, Purdue University, USA*
bwaldorf@purdue.edu

ABSTRACT

The study investigates the role of agriculture in the process of urbanization. According to Matsuyama (1992), the relationship between agricultural productivity and urbanization depends on the economic openness. In closed economies the relation is positive while for open economies it is negative. This paper empirically tests the role of agricultural productivity on a country's level of urbanization through a spatial econometric regression model that allows for smooth coefficients. Spatial autoregressive errors are included in the model to account for unobservable spatially correlated natural, social or historical factors that may determine urbanization levels. The slope coefficient of agricultural productivity on urbanization is modeled as a smooth transition function of countries' degree of openness to allow for variation by openness. The models are estimated using cross section samples of countries, separately for 1990 and 2005. Our results show that the effects of agricultural productivity on urbanization are positive for closed economies and decrease with the degree of openness. Moreover, we find a significant coefficient differential between closed and open economies.

Keywords: agriculture, urbanization, openness, smooth coefficient model
JEL code: C14, C31, O13

1 Introduction

Rapid urbanization is one of the most prominent features of today's world development. In general, urbanization can be described as a process of the world transiting from a predominantly rural, agricultural world to a predominantly urban, non-agricultural world. On a formal level, urbanization refers to the proportion of the population that lives in urban areas, or to the rise thereof [1]. Since the industrial revolution the world experienced a rapid increase of the urban population share. According to the United Nations, the global percentage of the urban population rose dramatically from 13% (220 million people) in 1900 to 29% (732 million people) in 1950, and in 2007 the urban population exceeded the rural population for the first time in history (UNFPA, 2007). Figure 1 shows the urban and rural population sizes since 1950 and projected to 2030.

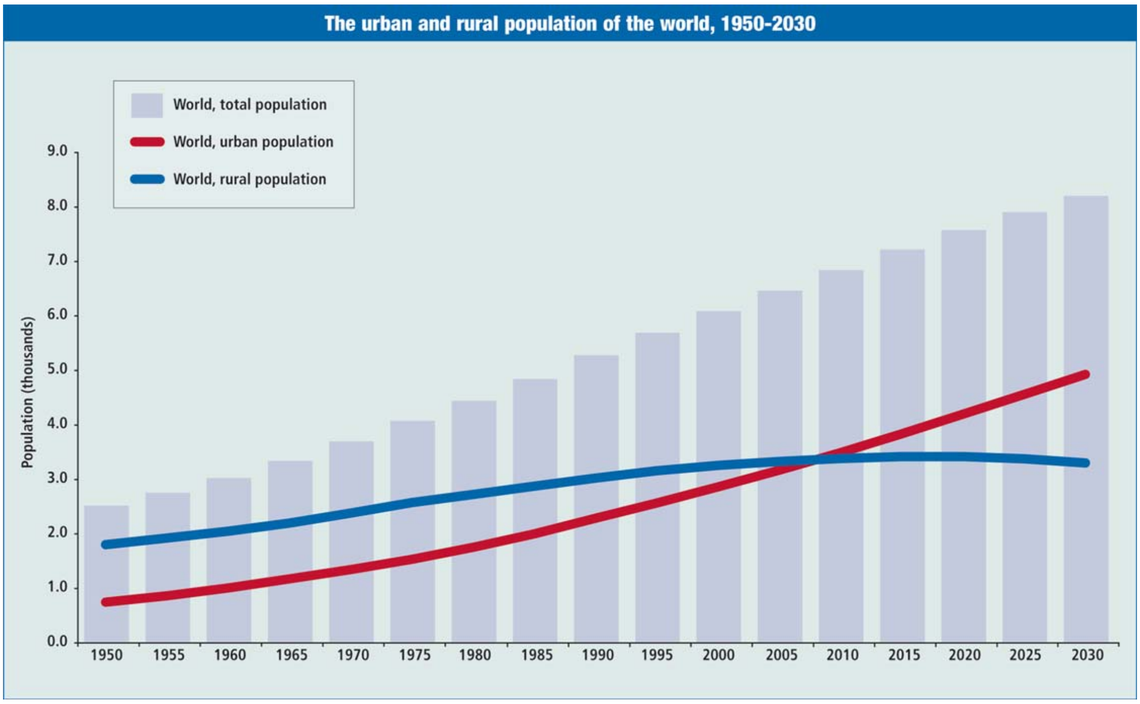

Figure 1: Estimated and Projected World Urban and Rural Population (Source: UN Population Division)

[1] Demographically, there is a difference between urbanization as the rise in the proportion of the urban population and urbanization as the proportion of the urban population. However, the literature does not always make a clean distinction and uses the term urbanization both to describe the rate of increase and the level. In our empirical model, we use of the term urbanization to refer to the level of urbanization.

This paper examines the role of agriculture in the urbanization process. We expand on Matsuyama's (1992) theoretical contribution that links the effect of agricultural productivity on urbanization with the openness or closeness of an economy. Central to Matsuyama's theoretical model is the proposition that agricultural productivity has a positive effect on urbanization in closed economies, and a negative effect in open economies. While Matsuyama's theoretical model is based on a dichotomous distinction between closed and open economies, we empirically test a model of urbanization in which the effect of agricultural productivity on urbanization is allowed to vary by the *degree* of openness.

We empirically test the above mentioned relationship between agricultural productivity and urbanization. In order to capture the variation of the relationship by openness, the slope coefficient of agricultural productivity on urbanization is modeled as a smooth transition function of a country's degree of openness. Spatial autoregressive errors are included in the model to account for unobservable spatially correlated natural, social or historical factors that may determine urbanization levels.

Using a sample of 148 countries in 1990, and a sample of 180 countries in 2005, we find that the effect of agricultural productivity on urbanization is positive for closed economies and decrease with the degree of openness. Moreover, we find a significant coefficient differential between closed and open economies.

The paper is divided into six sections. Following this introduction, the second section provides a conceptual discussion of the role that agricultural productivity plays in the urbanization process. The third section provides the formal model specification, followed by the data description in the fourth section. The results are presented in the fifth section. Conclusions and future research directions are discussed in the last section.

2 Background

2.1 The positive role of agricultural productivity

Industrialization, which greatly improved urban productivity, is commonly believed to trigger modern urbanization. It is seen as a "pull" force that motivates people to move from rural to urban areas. However, even if a country experiences large increases in urban sector production, a good deal of its labor force has to remain in rural areas unless agriculture can provide the necessary productivity gains to feed the urban population (Tolley and Kripalani , 1974). Not surprisingly, thus, Motamed et al. (2010) find that locations with more favorable natural agriculture endowments tend to get urbanized earlier in history.

Improvement in agricultural productivity is hence believed to be an important contributor to the urbanization process. The argument is that higher agricultural productivity provides food and other agricultural products with less manpower and thus allows for a shift of labor out of agriculture and into industry. The low urbanization level in ancient times can be largely attributed to low agricultural productivity such that it took many cultivators to support one man in the city (Davis, 1955). From this point of view, agricultural improvements make it possible that the size of the urban population grows, and are a precondition for urbanization. Looking at the economic structural transformation as a whole, agricultural productivity improvement is the necessary force to "push" labor into urban activities.

Few studies explicitly address the relationship between agriculture and urbanization, but there is a large body of literature discussing the role of agriculture in industrialization and economic development. Since urbanization and industrialization are typically seen as synonymous and being associated with economic development (Todaro and Smith, 2002), the arguments in studies about agriculture's effects on industrialization and economic development can be similarly applied to urbanization.

Many studies, especially earlier ones, agree that agriculture improvement is a precondition to industrialization and economic development [2]. A commonly cited example is that the Industrial Revolution in Britain would not have been possible without the Agricultural Revolution that preceded it (Nurkse, 1953) [3]. The development-stage theory (Rostow 1960) posits that revolutionary changes in agricultural productivity are an essential condition for successful take-off in economic development. Numerous studies have echoed that argument(e.g., Schultz, 1964; Timmer, 2002; Gollin et al, 2002) and fostered the idea that growth in the agriculture sector could be a catalyst for the inter-sectoral resources transformation into an industrialized economy.

Johnston and Mellor (1961) list five ways of how agriculture contributes to overall economic growth: (1) supply of food for urban sectors; (2) supply of foreign exchange from agricultural export; (3) supply of surplus labor for industrial sector; (4) supply of savings for industrial investment; (5) provision of domestic market for industrial expansion. Note that all five mechanisms rely on and facilitate urbanization. Urbanization is therefore the key intermediate step in many economic models addressing the role of agriculture in economic growth (e.g., Lewis, 1954; Matsuyama, 1992; Gollin, 2002). More specifically, the inter-sectoral transition from the traditionally stagnant agricultural sector to modern industrial sectors fosters economic growth. Given that industries are predominantly located in urban areas, urbanization is an indicator for the inter-sectoral transition and ultimately economic growth. Moreover, though seldom stated explicitly in the development literature, economic growth models suggest that increasing urbanization further propels growth (Gollin et al 2012). Many empirical analyses on inter-sectoral linkages also provide evidence that agriculture growth is an engine of economic growth (Awokuse, 2009). As such, the economic growth studies indirectly provide clues that point to agricultures positive role for the process of urbanization.

[2]For a more detailed literature review, see Awokuse (2009), Dethier and Effenberger (2012).

[3]Historians have long believed that the modern world commenced in Britain in the 1770s with simultaneous industrial and agricultural revolutions. However, there is still debate about the role of agricultural revolution. Clark (2002) estimates the output per acre and output per worker in England from 1500 to 1912 and finds agricultural productivity did not grow so much, and the growing population of Industrial Revolution England was fed mainly through food imports and through switching agricultural output towards food, not through an agricultural revolution.

2.2 The negative role of agricultural productivity

A corollary of the rural-urban migration literature is that agricultural productivity gains serve as an impediment of urbanization. According to the seminal work by Lewis (1954) and Harris and Todaro (1970), the urban/rural wage differential is the main driving force underlying the decision to migrate from rural to urban areas. While wages are ultimately determined by productivity, the improvement of agricultural productivity increases rural wages and discourages people to move to urban areas. The effect is similar to the resource movement effects in the "Dutch Disease" (Corden and Neary, 1982).

Many studies in the migration literature find that adverse rural conditions, including low wages in rural areas, facilitate rural to urban migration (Kamerschen 1969; Pandey 1977; Firebaugh, 1979). Similarly, studies on over-urbanization posit that rural poverty is one of the main contributors to rapid urban growth (Barrios et al., 2006). An example is the development gap between the southern portion of the U.S. and New England. Despite the advantages of the more arable South of the US, it ended up lagging behind in industrialization and urbanization compared to New England (Field, 1978; Wright, 1979). Similarly, during the 1970s to 1990s, many agricultural resource rich Asian countries fared worse than their newly industrialized neighbors such as Hong Kong, Singapore, and South Korea, all of which lacked large quantities of arable land (van der Ploeg, 2011). These examples are seen as strong support for the idea that it is a depressed, rather than a flourishing agricultural sector that ultimately leads to high urbanization.

2.3 Reconciling opposing views

To reconcile this seemingly conflicting roles of agriculture in urbanization, Matsuyama (1992) proposes that the openness of economies needed to be taken into account. If the economy is a closed system, food and other agricultural products can only depend on self-supply, and so agricultural productivity has positive effect on urbanization. But if the economy is an open trading system, it can always purchase food from outside markets, and thus economies with less rich agriculture endowment happen to possess initial comparative (not necessarily absolute) advantage in

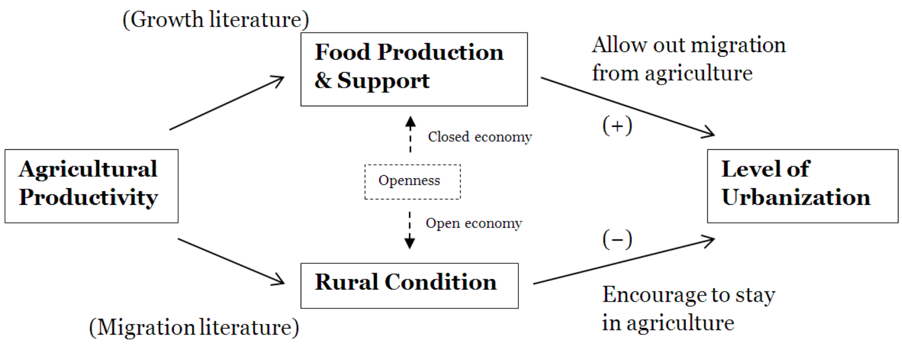

Figure 2: Effect of Agriculture on Urbanization

industries, and may rely on imported agricultural products and realize faster industrialization and urbanization. Thus, for open economies agricultural productivity turns to be a negative effect for urbanization. Those relations can be illustrated in Figure 2.

3 Model Specification

Matsuyamas (1992) theoretical model forms the foundation of the empirical model. In his model, it is assumed that the economy is composed of two sectors: agriculture and manufacturing. Let U_t be the share of the manufacturing (urban) labor force at time t, then agricultural output, X_t^A, and manufacturing output, X_t^M, at time t can be expressed as:

$$X_t^A = A \times G(1 - U_t) \qquad G(0) = 0,\ G' > 0,\ G" < 0, \tag{1}$$

$$X_t^M = M_t \times F(U_t) \qquad F(0) = 0,\ F' > 0,\ F" < 0, \tag{2}$$

where $G()$ and $F()$ denote production functions for agriculture and manufacturing, respectively, and A and M_t are multipliers representing the productivity in agriculture and manufacturing, respectively. Note that the specification is based on the assumption that labor is the only input for the economy. Furthermore, it assumes that agricultural productivity is exogenous, whereas the manufacturing sector is allowed to grow endogenously through learning-by-doing.

Matsuyama shows that, in equilibrium, the share of manufacturing labor (urbanization level) is positively linked to agricultural productivity if the economy is closed. In contrast, if the economy is open, agriculture and urbanization are inversely related:

- For closed economy: $U \propto A$ (+)
- For open economy: $U \propto A$ (-)

We extend Matsuyamas model by replacing the open-closed dichotomy with a more nuanced representation of openness, that is, we envision that economies differ along a continuum of openness where Matsuyamas "open economy" and "closed economy" are the two endpoints at the extremes. Towards that end, we regress urbanization, U, on agricultural productivity, A, and a set of control variables $\mathbf{X}$. Most importantly, the specification is such that the effect of A on U is allowed to vary in accordance with a smooth transition function, $\mathbf{g}$:

$$U = (\beta + \delta \cdot \mathbf{g})A + \mathbf{X}\eta + \varepsilon \tag{3}$$

$\mathbf{g}$ is a function of economic openness for example measured via trade of transportation variables and thus different degrees of openness will result in different coefficients $\beta + \delta \cdot \mathbf{g}$. We adopt the commonly used logistic function:

$$\mathbf{g} = \frac{1}{1 + e^{-\gamma(Openness - c)}}$$

where γ and c are parameters to be estimated. The values of g range between 0 and 1, with the end points representing Matsuyamas ideal cases of closed and open economies, respectively.

Given this specification, the effect of agricultural productivity on urbanization equals $\beta + \delta \cdot \frac{1}{1+e^{-\gamma(Openness-c)}}$. The coefficients for the two extremes of closed and open economy are β and $\beta + \delta$ (or $\beta + \delta$ and β, depending on $\gamma > 0$ or < 0) respectively. It is expected that as openness increases the effect of A on U declines. In addition, other than imposing structures on the transition function $\mathbf{g}$, we can also use semi-parametric or non-parametric methods to estimate $\mathbf{g}$.

The set of control variables, ($\mathbf{X}$), includes three variables. First, since urbanization is not only influenced by the "push" force from agricultural productivity growth in rural areas, but also by the "pull" of growing industrial productivity in urban areas, the model controls for urban productivity. In some sense, the urban "pull" is a much stronger force, especially considering the rapid urbanization of the world since the Industrial Revolution. Thus, it is important to control for how attractive the urban sectors are for potential migrants (such as agglomeration effect, job creation, and amenities) and for the urban capacity to accommodate the increasing population (such as infrastructure, public health, and social institution). Both of those factors are related to the urban productivity. Second, since a country's dependency on natural resource exports may spur additional urbanization, regardless of the level of industrialization (Gollin et al 2012), we include a control for natural resource dependency. Finally, as discussed in the background section, the rationale underlying the link between agriculture and urbanization is their joint connection with industrialization and economic development. Thus, we expect that the model will fit better for developing countries than for the fully developed countries and use a dummy to distinguish between the two types of countries.

To account for unobservable and missing variables and their potential spatial correlation, we include spatial autoregressive errors in the model:

$$\varepsilon = \lambda W \varepsilon + \mu$$

where λ is the spatial autoregressive coefficient, W is the weight matrix, and μ represent the classical independent and identically distributed (i.i.d) error terms with a mean of zero with variance σ^2. The weight matrix is specified via inverse spherical distances between the centroids of country polygons. The cut-off point is set to 3000 kilometer. On average each country has about 15 neighbors.

4 Data

This study uses country-level data to estimate the relation between agricultural productivity and urbanization. Country level agricultural production data are taken from the FAO database. Population, economic development, and trade data are from World Bank's World Development Indicators. One advantage of using countries as the units of analysis is that countries are usually the natural boundary for rural-to-urban migration, and thus fit the two-sector economic model well. The databases cover the period from 1960 to 2010 for most variables. However, agricultural labor data are only available since 1990.

The measurements of variables in the study are as follows:

(1) Urbanization Level

Urbanization (percent urban) is measured as the urban population expressed as a share of the total population. [4] It ranges from 0 to 100, and the unit is percentage point.

$$U = \frac{Urban\ Population}{Total\ Population}$$

(2) Agricultural Productivity

Agricultural productivity is measured as gross agricultural production per worker:

$$A = \frac{Gross\ Agricultural\ Production}{Agricultural\ Workers}$$

Gross agricultural production is the sum of quantities of different agricultural commodities produced weighted by 1999-2001 average international commodity prices (in constant international dollars). Agricultural workers are measured as economically active population in agriculture. Note that , if so defined, A measures labor productivity, not total factor productivity. Although the inadequacy of the labor productivity measure has long been criticized and many researchers favor total factor productivity (for example, Fabricant, 1959; Christensen 1975), we deem it appropriate for our study. In fact, since we focus on the influence of the productivity if one unit of labor can produce and the influence of that on the labor inter-sectoral allocation, the labor productivity may be even more appropriate than total factor productivity.

Figure 3 visualizes the bivariate relation between agricultural productivity and

[4] It should be noticed that there is no universal standard for distinguishing urban from rural areas yet. The data are based on each country's own definition of urban areas.

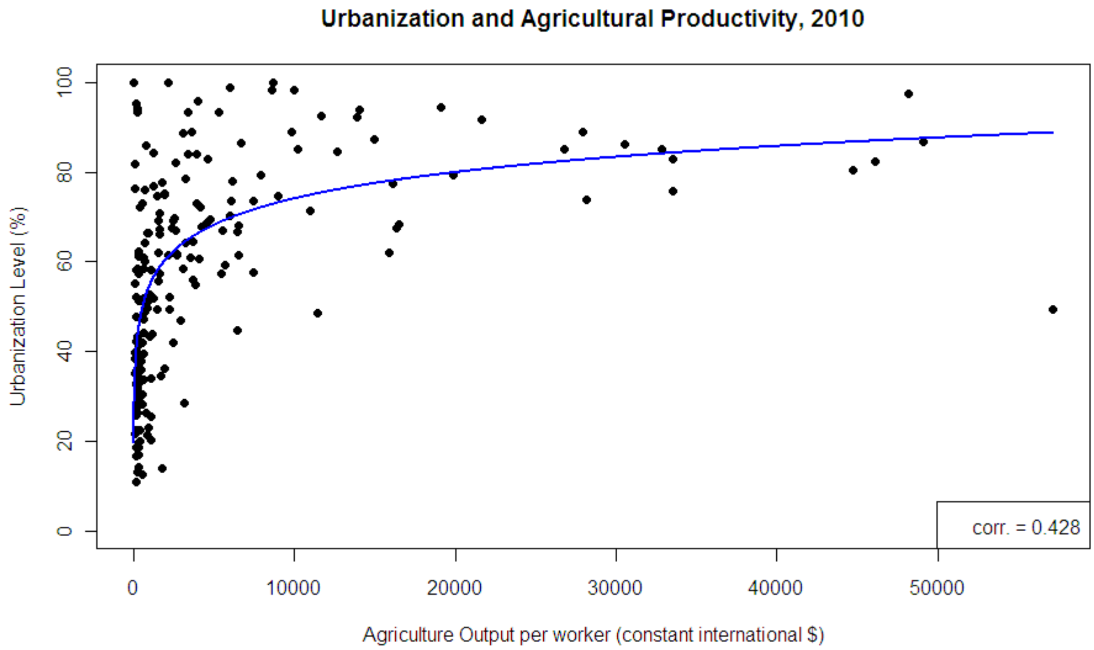

Figure 3: The Relation between Urbanization and Agricultural Productivity, All Countries in the World

urbanization for all countries of the world in 2010.It demonstrates clearly that, on average, countries with higher levels of agricultural productivity also have a high urbanization level. As there are some extremely high values of agricultural productivity while urbanization is upper bounded as 100 percent, a natural logarithm function of agricultural productivity better describes the relation.

(3) Economic Openness

Economic openness is a vague concept and not easily measure. In this study we follow the commonly used strategy of measuring the degree of economic openness via international trade dependency, that is, as the ratio of the sum of import and export in the numerator and GDP in the denominator. The distribution of trade openness for selected years are shown in Figure 4, revealing that countries' trade openness increased over time.

Figure 5 shows the relationship between agricultural productivity and urbanization for three groups of countries in 2010. The first group is comprised of countries with relatively closed economy, defined as those with an openness measure of less

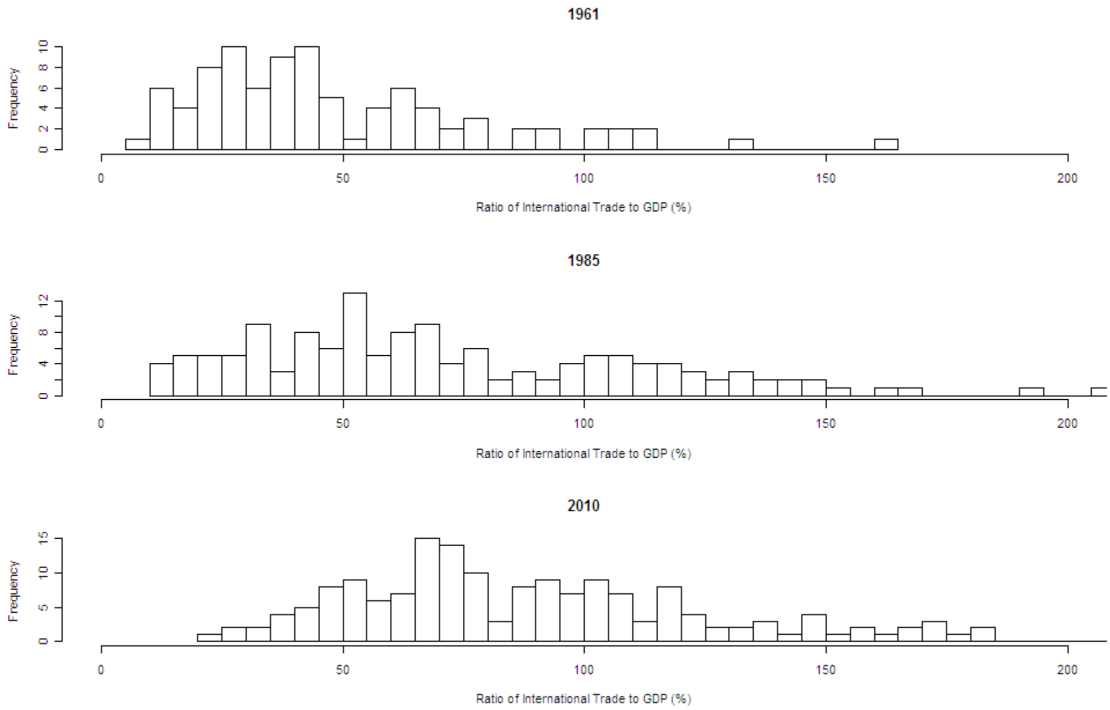

Figure 4: Distribution of Trade Openness, Selected Years

than 75%. Consistent with the Matsuyama model, the relationship is positive. The second group includes countries with more open economies, i.e., those with an openness measure exceeding 75%. In contrast to Matsuyamas model, the open economies also display a positive association between urbanization and agricultural productivity. However, the magnitude of the slope is smaller than for the closed economies. Finally, the third group includes countries with missing trade data and reveals a weak but positive association between urbanization and agricultural productivity.

To deal with the missing trade data, we also explore the use of population size as a proxy for openness. Generally, it is expected that larger countries have more resources to build up a more comprehensive industry system, have bigger domestic market, and thus are more likely to be closed economies. Figure 6 demonstrates the negative correlation between country size and trade openness. Moreover, as Figure 7 shows, the urbanization-agriculture relations also differ clearly by country size, where with the slope being steeper for larger (less open) countries than for small (more trade dependent) countries.

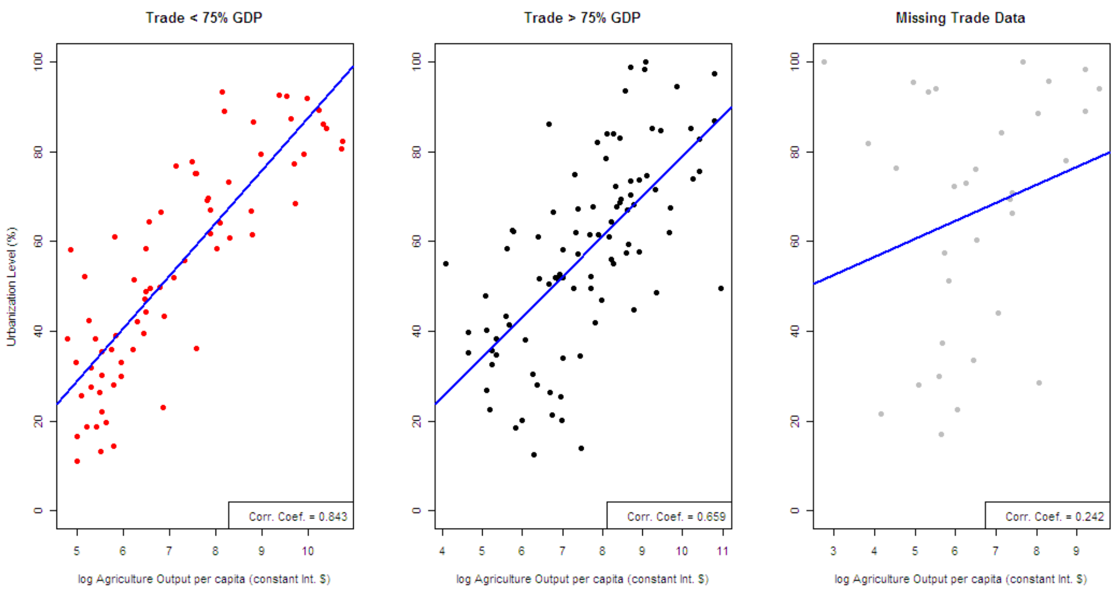

Figure 5: Urbanization and Agricultural Productivity, by Trade Openness, 2010

(4) Industrial Productivity

Industrial productivity controls for the urban "pull" side force of urbanization and is measured by industry value added per worker, in real dollars. Higher industrial productivity is associate with higher urbanization level (see Figure 8). The relation takes a natural logarithm form.

(5) Natural Resource Exports

Natural resource exports as share of GDP (%). Across countries, higher natural resource exporters do have higher urbanization level, but the connection is not very strong (see Figure 9).

5 Results

Table 1 and 2 displays the estimation results for a sample of 148 countries in 1990, and a sample of 180 countries in 2005. We allow both the intercept term and slope

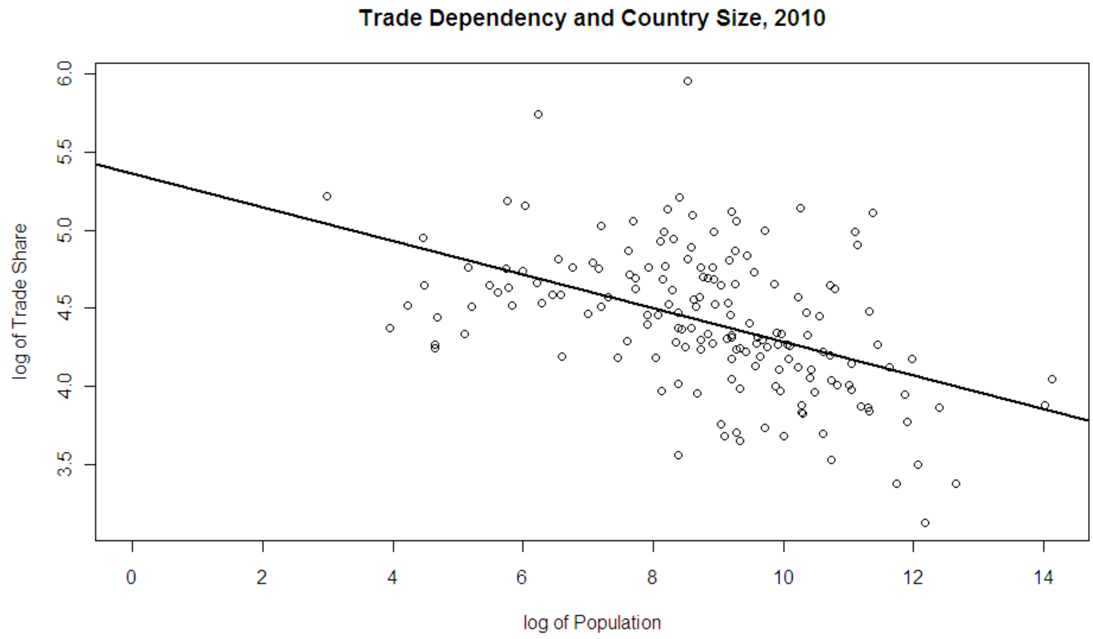

Figure 6: Trade Openness and Country Population Size, 2010

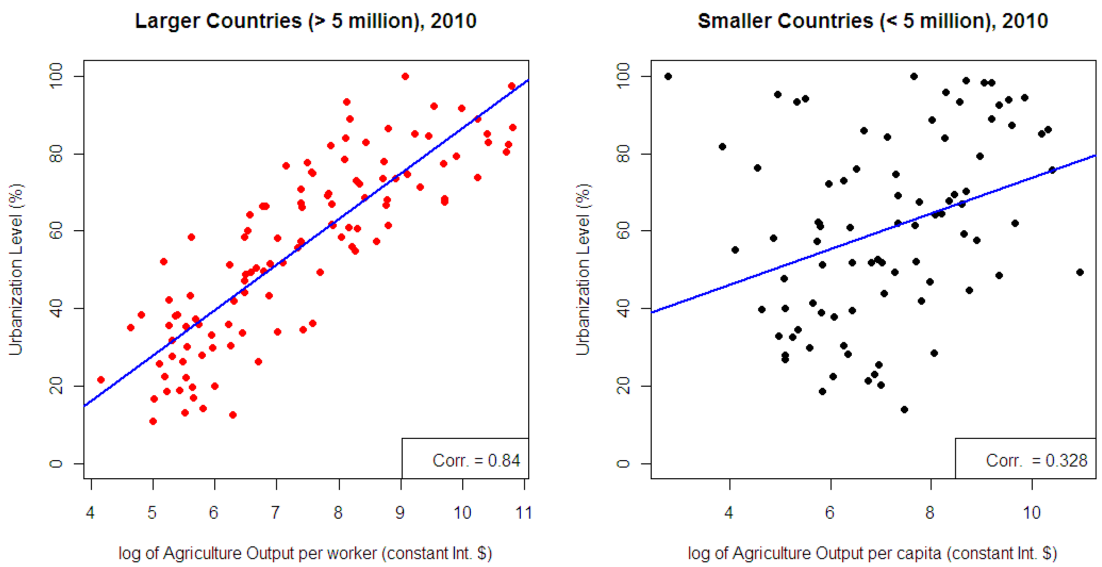

Figure 7: Urbanization and Agricultural Productivity, by Population Size, 2010

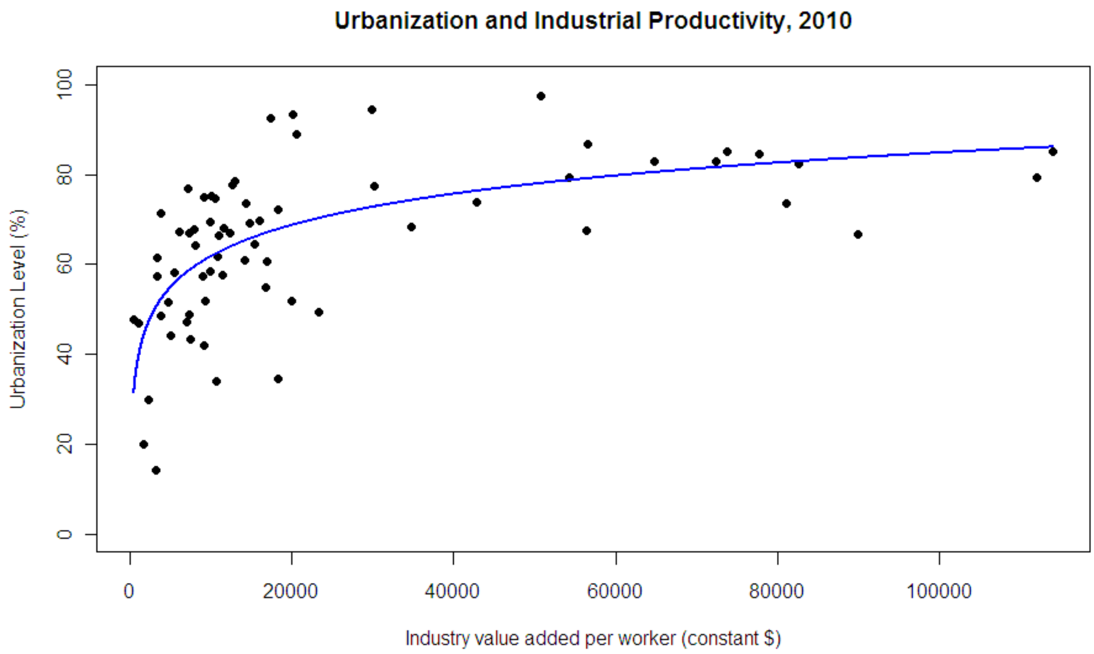

Figure 8: Urbanization and Industrial Productivity, 2010

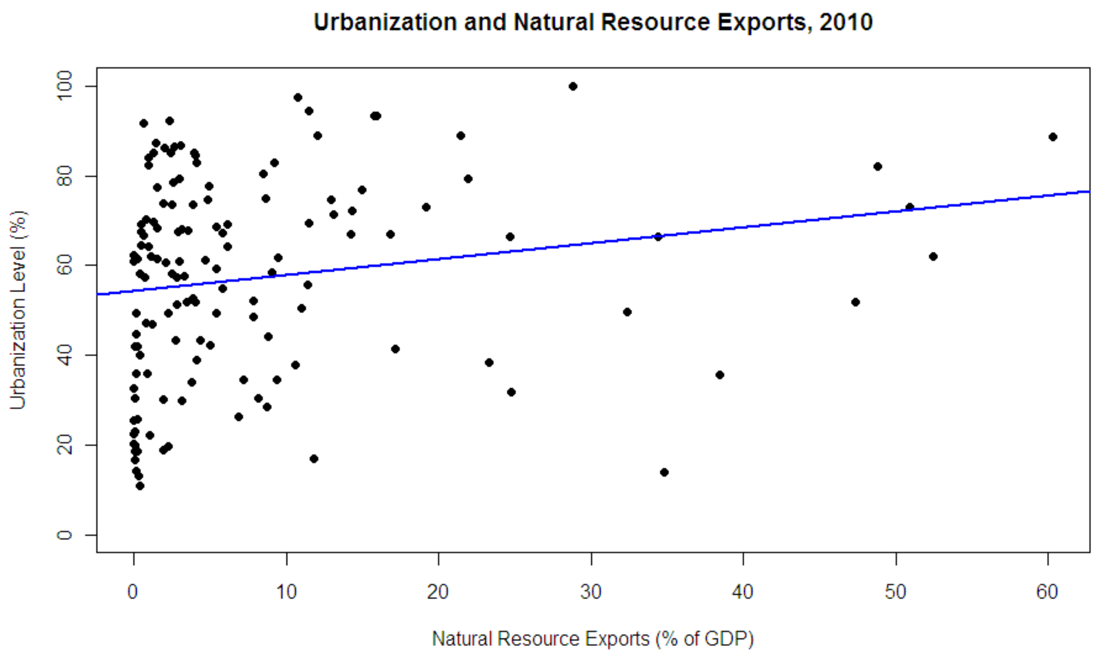

Figure 9: Urbanization and Natural Resource Exports, 2010

coefficient of agricultural productivity to vary with openness.

We begin with an OLS model (column (1)) in which openness is measured by a dummy variable Open that takes on the value 1 if trade $> 75\%$ and 0 otherwise. The results show that for both years, agricultural productivity is significantly positively associated with urbanization. Moreover, the slope is significantly (10% level in 1990, 1% level in 2005) bigger for closed economies than for open economies. From the completely closed economies to the completely open economies the slope coefficients decrease by about 1/5 to 1/3. That means for open economies the positive association between agriculture and urbanization is less than that of closed economies. Moreover, the results of Model (1) also show substantial differences between developed and developing countries. In 2005, but not in 1990, the slope of agricultural productivity is significantly smaller for developed countries than for developing countries; in developed countries with an open economy the slope is even estimated to be negative. As expected, industrial productivity is positively related with urbanization, more so in developing countries than in developed countries, and natural resource export has a significant positive slope in 2005, but not in 1990. These results suggest that the urbanization and agriculture story is more a story about industrialization, economic transformation, and development. Thus, it is more suitable for countries passing through the various stages of development. In contrast, for the already fully developed economies, urbanization may no longer be closely related to agriculture. The OLS results change little when correcting for spatial autocorrelation (column (3)).

Column (2) show the results when using a logistic transition function that allows for the smooth change of the slope coefficient associated with agricultural productivity. The estimation of parameters is nonlinear least squares. In Column (4) are the estimates from the a nonlinear regression with both logistic smooth transition function and spatial autoregressive errors. The estimation steps follow a iteration procedure suggested by Florax et al (2009).

The smooth transition function confirms the general trends found in the linear OLS model but yields more nuanced results. For closed economies the urbanization level is positively associated with agricultural productivity. The slope coefficients of agricultural productivity (β_1) are positive and statistically significant, and are robust for different specifications. The coefficient of the interaction of openness and agricultural productivity (δ_1) are negative, though not statistically significant for some specifications and for some years. From the completely closed economies to the completely open economies the slope coefficients decrease by about 1/5 to 1/3. That means for open economies the positive association between agriculture and urbanization is less than that of closed economies. For example, in 2005, holding other factors fixed, when the agricultural productivity doubles the urbanization level is expected to increase by about 10 percentage points. At the same time, for open economies the increase is about 7 $\sim$ percentage points. When taking a more detailed look at how the slope coefficient changes with economic openness, however, it is found that the estimated parameters (γ and c) in the smooth function $\mathbf{g}$ are insignificant. It could be that the logistic functional form does not fit the openness change pattern very well. Thus, though we find in general the positive linkage between agricultural productivity and urbanization become weaker as economies become more open, we do not know exactly the functional form of openness yet. Those findings can serve as evidence to support the main idea of this paper that, country's urbanization level is positively linked to its agricultural productivity, while this positive linkage becomes weaker as country's degree of openness increases.

Figure 10 and 11 plot changing coefficient of agricultural productivity on urbanization across the openness continuum. The coefficient decreases with increasing openness. However, since the slope parameter for the transition function (c) is not statistically significant the exact shape may not accurately represented by these graphs.

Table 1: Regression, Varying Coefficients, 1990

Dependent Variable: Urbanization Level (%)				
	(1) Dummy	(2) Smooth	(3) Spatial Error	(4) Smooth Spatial Error
Intercept	-135.20 ***	-126.61 ***	-121.67 ***	-117.55 ***
	(15.85)	(14.40)	(15.37)	(12.26)
Open	24.02		6.58	
	(15.53)		(13.77)	
ln(Ag Prdc)	10.37 ***		7.23 ***	
	(2.04)		(1.99)	
ln(Ag Prdc)×Open	-4.73 *		-1.49	
	(2.41)		(2.18)	
β_1, $\mathbf{g}$=0		7.38 ***		5.13 ***
		(1.63)		(1.43)
δ_1, $\mathbf{g}$=1		1.37 **		1.96 **
		(0.53)		(0.64)
γ, slope parameter		-0.18		-0.16
		(0.28)		(0.24)
c, location parameter		78.78 ***		83.21 ***
		(9.97)		(17.52)
Developed	127.73 ***	117.13 **	111.98 ***	122.71 **
	(44.67)	(45.10)	(39.32)	(42.13)
ln(Ag Prdc)×Developed	-4.12	-2.77	0.64	-2.65
	(3.89)	(3.66)	(3.70)	(3.88)
δ_1, ln(Ag Prdc)×Open×Developed	1.37	-0.19	-0.36	-2.01
	(1.21)	(1.14)	(1.07)	(1.58)
ln(Industry Prdc)	12.89 ***	13.30 ***	13.84 ***	12.99 ***
	(1.72)	(1.74)	(1.52)	(1.65)
ln(Industry Prdc)×Developed	-10.49 **	-10.20 **	-12.63 ***	-11.34 **
	(5.07)	(5.11)	(4.35)	(5.98)
Natural Resource Export (% GDP)	0.09	0.09	0.05	0.78
	(0.12)	(0.12)	(0.11)	(0.13)
Africa	14.35 ***	12.87 ***	11.11 *	13.05 ***
	(4.21)	(4.18)	(5.78)	(4.56)
Asia	9.58 **	7.65 *	6.26	7.23 *
	(4.03)	(3.99)	(5.92)	(4.01)
Latin America	5.83	5.05	9.13	4.32
	(3.94)	(3.98)	(6.80)	(3.99)
λ, AR parameter			0.62 ***	0.82 ***
			(0.10)	(0.17)
AIC	1194	1196	1178	1196
Observations	148	148	148	148

Notes: (Asymptotic) Standard errors are reported in parentheses: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 2: Regression, Varying Coefficients, 2005

Dependent Variable: Urbanization Level (%)				
	(1) Dummy	(2) Smooth	(3) Spatial Error	(4) Smooth Spatial Error
Intercept	-112.23 ***	-75.90 ***	-107.37 ***	-68.26 ***
	(13.41)	(11.04)	(13.22)	(12.11)
Open	37.24 ***		37.54 ***	
	(12.23)		(11.35)	
ln(Ag Prdc)	13.60 ***		11.71 ***	
	(1.81)		(1.84)	
ln(Ag Prdc)×Open	-6.19 ***		-5.98 ***	
	(1.83)		(1.70)	
β_1, **g**=0		5.05 ***		5.05 **
		(1.67)		(2.06)
δ_1, **g**=1		3.22 **		4.24
		(1.59)		(3.03)
γ, slope parameter		-0.55		-0.18
		(1.20)		(0.36)
c, location parameter		95.51 ***		92.21 ***
		(4.84)		(10.61)
Developed	90.49 **	80.31 **	89.34 **	75.76 *
	(36.96)	(36.20)	(35.29)	(38.68)
ln(Ag Prdc)×Developed	-9.23 ***	0.10	-6.15 *	-4.47
	(3.28)	(3.28)	(3.23)	(5.61)
δ_1, ln(Ag Prdc)×Open×Developed	2.32 ***	0.61	1.94 ***	6.35
	(0.79)	(2.49)	(0.72)	(6.04)
ln(Industry Prdc)	7.78 ***	8.64 ***	8.95 ***	7.72 ***
	(1.40)	(1.34)	(1.38)	(1.36)
ln(Industry Prdc)×Developed	-2.57	-8.78 **	-5.08	-8.16 **
	(4.07)	(3.68)	(3.84)	(3.79)
Natural Resource Export (% GDP)	0.21 **	0.10	0.12	0.05
	(0.09)	(0.08)	(0.08)	(0.09)
Africa	11.29 ***	6.53 **	7.38	6.89 *
	(3.85)	(3.28)	(5.17)	(3.54)
Asia	3.23	0.45	1.43	0.16
	(3.38)	(3.19)	(4.56)	(3.48)
Latin America	4.64	-0.37	5.76	-0.91
	(3.70)	(3.42)	(6.00)	(3.60)
λ, AR parameter			0.56 ***	0.80 ***
			(0.11)	(0.21)
AIC	1462	1477	1452	1476
Observations	180	180	180	180

Notes: (Asymptotic) Standard errors are reported in parentheses: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

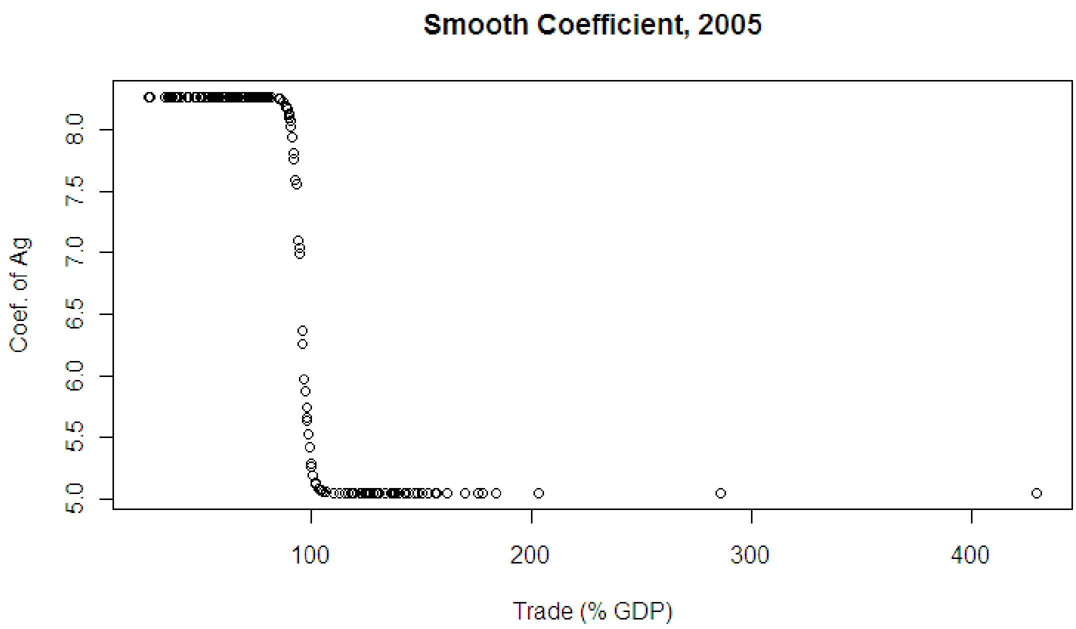

Figure 10: The Changing Coefficient, Nonspatial Model, 2005

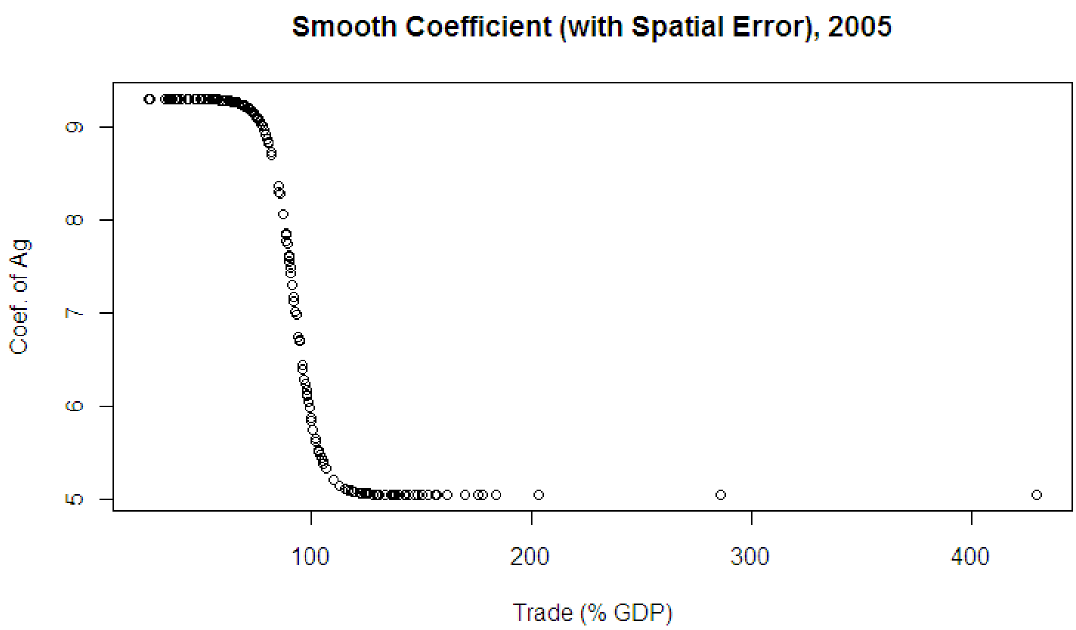

Figure 11: The Changing Coefficient, Spatial Model, 2005

6 Conclusion

This paper empirically tests the association between agricultural productivity and country's level of urbanization through a spatial error model that allows for smooth coefficients. Using cross-sections of world countries as samples, it is found that the association is affected by economic openness. For closed economies, urbanization is significantly positively associated with agricultural productivity. The association becomes weaker with increasing openness of the economy. Although the error terms are spatially autocorrelated, adding spatial error terms in the regression does not change the conclusions very much. More worrisome is that the logistic transition function does not describe the smooth pattern well. This could be due to, for example, the logistic functional form being ill-suited, or due to trade dependency being a poor measure of economic openness.

Future research will focus on the following issues. First, since urbanization, U, is bounded between 0 and 1, future research will explore using a fractional logit instead of the linear form presented in this paper. Second, we will design a better measure of agricultural productivity. In its current form, agricultural productivity is subject to production fluctuation, dollar value changes, land constraints and reciprocal effect. Third we will experiment with alternative measures to capture the openness of economies. Finally, we will extend the smooth coefficient regression estimation from parametric to semi-parametric and non-parametric approaches.

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