# Productivity Growth, Spatial Inequality and Returns to Scale:

# The Case of the Cities of the Province of Jiangsu, China

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## Abstract

China's rapid growth over the past few decades has been associated with widening regional disparities. However, this paper focuses on the causes of spatial disparities within the province of Jiangsu, one of China's most developed and fastest growing regions. It tests two competing models of regional growth using data for total value added (GDP) and industry for the 61 cities of the province over the period 1996 to 2012. The first is the standard Solow neoclassical growth model with its assumption of constant returns to scale. This provides evidence of convergence in the sub-period from 2006-2012 but not in the earlier sub-period. The second model that is estimated is the Verdoorn law, which allows for encompassing increasing returns (including induced technical change and agglomeration economies). The results find a statistically significant Verdoorn coefficient for both total output and industry. The estimates suggest substantial increasing returns to scale. There is also evidence of a significant diffusion of innovations from the more to less technologically advanced cities. The two models are nested in that both can be viewed as being derived from a production function, and the evidence rejects the hypothesis that the cities are subject to constant returns to scale. Finally, in an effort to understand changes in the degree of regional disparities in Jiangsu, this paper utilises the Theil framework to investigate into causes of disparity across the three regions of Jiangsu, and the result confirms that inequalities in education and infrastructure can be important sources of income disparity.

*Key-words*: inequality, city productivity growth, returns to scale, Jiangsu China, Verdoorn's law, Solow growth model

## 1. Introduction

'Economic activity arises, grows and develops in space… Productive resources are distributed unevenly in space' (Capello, 2007: 1). Regional economics involves the study of patterns of regional growth and the reasons for the divergent development paths. There is a large literature on regional inequality in the developed countries, such as UK, EU, and US. The existing literature on China's regional issues focuses primarily on disparities across provinces, while few studies pay attention to the striking regional inequality within the provinces, and between their cities. Because of the size and scale of China, as well as the diverse policy objectives of each province, studying cross-regional disparities merely at the national level needs to be supplemented by a consideration of intra-province disparities, especially for the cities.

The first objective of this paper is first to examine the validity of various regional growth theories in the context of China, taking the cities of Jiangsu Province as a case study. The contrasting neoclassical growth model and Verdoorn law will be empirically tested. The second objective is to quantify the degree of spatial productivity disparities within the Province, evaluate the changing trends of inequality, and investigate the underlying causes of output disparity.

Jiangsu Province provides an interesting case study of the determinants of spatial economic disparities. The province is one of China's most prosperous regions, but it also exhibits a pronounced North-South divide. As Rozelle (1994) points out, Jiangsu Province consists of three regions that are both developed and lagging in terms of economic development. Also, it is recognised that many typical institutions embedded in the reforming economy of China can be found in Jiangsu, for example, a fast-growing rural industrial sector (Rozelle, 1994).

This paper is organized as follows. Section 2 is a review of relevant theories and literature on regional development. Section 3 provides an overview of the economy of Jiangsu Province. It analyses the importance of the Jiangsu economy, its striking regional disparities and its relevant regional policies. An analysis of regional policies will help assess the government's effort in bringing about balanced growth. Then, discussions on different approaches to analysing the regional disparity in Jiangsu, including the neoclassical growth model (section 4), Kaldor's growth laws, including the Verdoorn law (section 5) and the Theil index (section 6). Section 7 concludes.

## 2. Review of Regional Growth Theories

The World Development Report 2009 has identified three attributes of development, on which basis it is found that economic growth is usually initially unbalanced before converging (World Bank, 2009). The three characteristics are:

- Geographical unevenness. It is impossible to maximise the growth of productivity and simultaneously achieve balanced spatial growth because of agglomeration economies
- Circular and cumulative causation. Convergence in welfare can be achieved alongside increasing economic concentration.
- Neighbourhood effect. Although it is difficult for lagging areas to catch up in the early stages of development, spill-over and trickle-down effects may eventually bring about convergence.

In *Reshaping Economic Geography in China*, Huang and Luo (2009) find that the reformist policies post-1978 aim to reap the benefits of agglomeration economies by increasing the density of economic activities, overcoming issues related to distance (through the provision of infrastructure), and minimising internal and external barriers to produce a more integrated national market. They point out that since 1992 the accelerating marketization process has partly removed barriers that for many decades had set limits on the degree of factor mobility and commodity exchanges. Consequently, enterprises now have the incentive to base their decisions on comparative and locational advantages (He, 2009). However, the focus on developing rural enterprises and attracting foreign investments has led to wider regional inequalities (Huang & Luo, 2009). Huang and Luo (2009) consider that in the future there will be gradual convergence in *growth rates* between the more developed coastal region and the inland provinces, while the geographic advantage still matters.

The economic models frequently used in analysing regional disparities, paradoxically include both those based either on constant returns to scale, or on increasing returns and the process of cumulative causation. Theories of convergence, based on the neoclassical paradigm, examine reasons for diminishing inequility between developed and less developed regions, while theories of a Keynesian origin genberally try to explain the factors leading to persistent disparities (Capello, 2007: 9).

***The Neoclassical Growth Theory***

The neoclassical growth theory predicts that regional differences in productivity are due to different levels of factor endowments, notably the capital/labour ratio. The assumptions include constant returns to scale, diminishing returns to factors of production, perfectively competitive markets and free factor mobility. It also assumes that all regions have access to the same level of technology which is assumed to be a public god and freely available to all firms. Based on these assumptions, catch-up and regional convergence will take place. One of the earliest single-sector neoclassical models of regional growth developed by Borts and Stein (1964) assumes perfect competition in the goods market and production factors market, full employment, flexible remuneration of the production factors, perfect mobility of the production factors among regions, no interregional trade and substitutability between capital and labour in the production of goods. The prediction from the model is that all regions will experience the same steady-state rate of productivity growth, which is determined by the common rate of technical progress. Temporary differences in productivity growth rates will be solely due to regions differing from their equilibrium capital-labour ratios. If a region has a capital-labour ratio below its steady-state level, then it will have a transitory growth rate that is temporally faster than the equilibrium rate, and vice versa. The model does not have a compelling explanation as to why the regions are not at their steady-state capital-labour ratios, although it can invoke exogenous shocks.

***Cumulative Causation Theories***

By way of contrast, Williamson's (1965) inverted U-shaped trajectory explains the stages of development and disparities. It is shown that in the early stage of development, economic growth is concentrated and polarised in the central area because of the importance of agglomeration economies, before it spreads to peripheral regions and the less-developed sectors. The reasons for the initial widening gap include migration of skilled labour from the developed to less developed regions, net capital inflow into fast-growing areas, preferential economic policies, and limited inter-regional trade in resources. Peripheral regions are able to catch up in later stages of development, as a result of both push and pull effects. Therefore, the widening productivity disparities are nothing more than a natural process in the early stage of development, and there should be convergence at a later stage. However, this theory is criticised for being too optimistic. One critique is that less advanced regions might be over-reliant on traditional industries which do not necessarily need innovation and technological progress, and as a result regional disparities may be persistent in 'qualitative' as opposed to 'quantitative' terms (Capello, 2007: 94).

Finding the assumption of constant returns to scale implausible and the noting the inability of the neoclassical model to explain persistent or long-term divergent growth rates, Myrdal's (1957) cumulative causation model explains the regional (and national) growth process by assuming increasing returns at the territorial level. The processes of human capital accumulation and agglomeration economies lead to a cumulative cycle in which, under certain assumptions, developed regions constantly outperform the less developed areas.

Myrdal's verbal argument was subsequently developed by Kaldor (1970) and formalised in the Kaldor-Dixon-Thirlwall (KDT) model (Dixon and Thirlwall, 1975). This demand-oriented approach emphasises the growth of exports as a prime determinant of a region's economic performance (see Kaldor, 1970 and Dixon & Thirwall, 1975). The specification of the model is as follows:

$$y_t = \gamma x_t \qquad (1)$$

$$x_t = -\eta\pi_{t-1} + \delta\pi_z + \varepsilon z \qquad (2)$$

$$\pi_t = w - p_t \qquad (3)$$

$$p_t = r_e + \lambda y_t \qquad (4)$$

where $y$ is the growth of regional income, $x$ is the growth of exports, $\delta$ (< 0) and $\eta$ (< 0) are the price elasticities of demand for exports and $\pi$ is the rate of growth of prices, where the subscript $z$ denotes the growth prices in the export markets. is the growth of output in the region's export markets. $\varepsilon$ is the income elasticity of demand for the region's exports (and reflects non-price competitiveness and the regional structure of production). $w$ is the growth of regional wages (which, as noted above, is assumed to be at the national rate). $p$ is the productivity growth, $\lambda$ is the Verdoorn coefficient, and $r_e$ is the exogenous component in the Verdoorn Law. Equation (4) of the KDT model, namely, $p_t = r_e + \lambda y_t$, is the Verdoorn law, which is a production relationship between productivity and output growth. It explicitly includes output growth as a regressor to capture the effect of increasing returns on productivity growth, which will occur when the Verdoorn coefficient, $\lambda$, is greater than zero. Traditionally, empirical estimates find this takes a value of about one half. This clearly contrasts the assumption of constant returns in the neoclassical approach. The Verdoorn law will be discussed in detail later.

The cumulative nature of growth is shown by the fact that a faster growth of output leads to a faster growth of productivity through the Verdoorn law (equation (4)). A faster growth of productivity results, in turn, in a slower growth in regional relative prices through the price relationship (equation (3). (Regional wages are assumed to be set by national bargaining and therefore grow at the same rate in both the region under consideration and the rest of the economy.) This leads to a faster growth of exports by improving the region's price competitiveness, which in turn feeds back into a faster growth of output through the dynamic foreign trade multiplier (equation (1)). Thus, growth proceeds in a cumulative fashion.

If a lag is introduced in the equation (4), then the solution of the KDT model is expressed as,

$$y_t = \gamma(-\eta\pi_{t-1} + \delta\pi_w + \varepsilon\pi_t + \varepsilon r_e) + \varepsilon\gamma\lambda y_{t-1} \quad (5)$$

This solution shows that there are possibilities of both explosive (or implosive) growth and convergence. If $\varepsilon\gamma\lambda$ is greater than 1, then the system will experience either an explosive or implosive process and the result depends on the initial conditions (Dixon & Thirwall, 1975; Capello, 2007: 224). If $\varepsilon\gamma\lambda$ is less than 1, the system will converge to a steady-state rate of growth, but will differ between regions depending upon the values of ε. Kaldor argues that the underlying process will lead to explosive growth, but this will eventually be constrained by shortages on the supply side, which is not explicitly modelled. Dixon and Thirlwall (1975) are of the opinion that growth will converge to a steady-state rate.

***The New Economic Geography***

In many countries, labour force, production and business activities tend to agglomerate in a relatively few regions and in a small number of areas within that region, as reflected in the distribution of cities. The occurrence and persistence of agglomeration of production is due to increasing returns to scale in manufacturing, by which it is meant the cost of certain products decreases and revenue increases if goods are produced where production is concentrated at a high spatial density. A simple version of this model assumes that there are two regions with two sectors, i.e., agriculture and manufacturing, with goods in the manufacturing sector produced at increasing returns and agricultural products subject to constant returns, and transport costs are present (Capello, 2007: 229). Agriculture production is assumed to be immobile and split equally between the two regions. It can be shown that eventually one region will contain the whole of the manufacturing sector if the benefits of agglomeration more than offset the cost of shipping the goods to the other region to meet the demand there. Which region captures the manufacturing sector is determined by purely chance factors and which region gains an early start in attracting manufacturing firms. Self-sustaining concentration of production will occur if there are large economies of scale, low transport costs and sufficiently mobile factors (Krugman, 1991). Such effects are cumulative, and will eventually lead to a core-periphery structure. The process of agglomeration will end if, and only if, the centrifugal forces (negative externalities, including congestion and pollution) outweigh the benefits from agglomeration (centripetal forces).

Agglomeration economies foster labour market pooling, flow of ideas and learning opportunities, which will in turn stimulate urban or regional growth (Glaeser, 2000). It is also found that pro-business government policies generally attract firms and strengthen the so-called 'home market effects'. In a study on the georaphical location of foreign investments, Shatz and Venables (2000) find that 'FDI is spatially more clustered than other forms of production'. The locational preference of FDI is associated with the R&D spillover effects, level of confidence, intermediate goods supply and demand.

Moreover, it may be shown thathe new economic geography can provide the foundations of the Verdoorn law (see Fingleton, 2003). In an extended new economic geography model, which includes inputs from producer services,it is assumed that there are increasing returns that are internal to producer service sector firms. The theory developed by Fingleton (2003) leads to the reduced form of the static Verdoorn law linking the level of output, productivity, wage rates and the density of economic activity. Expressed in growth rate forn, this gives the traditionl Verdoorn law.

## 3. China's Economic Development

Prior to 1978, the Marxist principle of common ownership and of generalised egalitarianism, Stalinist practices of central planning and suppression of light industries, and Mao's emphasis on regional economic self-sufficiency formed the basis of regional policies (Demurger, et al., 2001). These policy instruments led to a halt of divergence in per capita incomes between coastal and interior regions (Wei & Fan, 2000). However, the balanced growth approach was criticised as *inefficient*, as overall economic development was sacrificed (Long & Ng, 2001). It was believed that balanced development was neither feasible nor proper in a low-income country, and that spreading investment evenly would potentially dilute the effect of investments (Fan, 1997).

Since Deng Xiaoping assumed office in 1978, the economic philosophy has shifted from egalitarianism to a more pragmatist uneven regional development, with a clear emphasis on efficiency, comparative advantage, foreign investment and trade (Wei& Fan, 2000; Long and Ng, 2001). Fan (1997) considers that Deng's most influential thought on regional development is the endorsement of efficiency. Deng believed that allowing some regions (and groups of people) to become rich first was a prerequisite for China as an entirety to prosper (Huang & Bocchi, 2009). Guided by the efficiency principle, the Deng administration started to distribute limited resources to regions with favourable factor endowments, with the hope that productivity growth would spill over to the lagging areas (Long & Ng, 2001). The emphasis on comparative advantage led to regional division of labour on the basis of factor endowments.

The roles of preferential policies, which include fiscal transfers and state bank loans to build the infrastructure, and geographic locations, are the primary focus of existing literature. Fan (1997) believes that the preferential price policy has led to an 'unequal exchange' and 'unfair competition' between coastal and inland provinces. In contrast, Demurger *et al.,* (2001) rejected the view that preferential policies contributed to the prosperity of coastal provinces. In a research on the geography, policy and regional development in China, the authors find that the role of the state was only important initially.But at the same time, Demurger *et al*., (2001) are of the view that the fiscal decentralisation led to a decline in the state revenue from 35% of GDP to 14% in 1992. As a result the national government lacked the capacity to provide subsidies for poorer provinces and to undertake poverty alleviation and infrastructure improvement projects in the lagging regions.

Geographic locations are an important contributory factor to regional disparities in China. Demurger et al (2001) find that the proximity to the coast or navigable rivers fostered not only the accumulation of FDI, but also the growth of the rural industrial sector. It is found that geographic location and infrastructure endowment account for a significant proportion of observed variations in economic growth among Chinese provinces (Demurger, 2000). Bao *et al.,* (2002) consider that due to the spatial and topographic advantages, the low transport and communication costs increased the return to capital. As a result of the higher returns, migrant labour and FDI flow were attracted to coastal regions during the post-1978 period in China. Bao *et al* (.,2002) use coastline length as a proxy for geographic advantage, and the coastline alone could explain over 60% of the differences in growth rates across Chinese provinces. However, the approach is problematic - some provinces have long but under-utilised coastlines, making the comparison of geographic advantage using coastline length variable problematical.

In addition, Candelaria, *et al.,* (2013) have shown that regional inequality in China is likely to persist as a result of structural and long-term factors, including industry composition. Kanbur and

Zhang (2005) find that regional disparity in China can be explained by the share of heavy industry, the degree of decentralisation, and the degree of openness. Wan, *et al.,* (2007) contend that globalisation, uneven domestic capital accumulation, and privatisation play an increasingly important role in contributing to regional inequality, while effects of location, urbanisation and dependency ratio are gradually decreasing.

***The Development Experience of Jiangsu Province***

Jiangsu Province is located on the East Coast of China, along the lower reaches of Yangtze River and Huai River. It is part of the Yangtze River Delta, one of the three economic belts of China. The province borders Shanghai Municipality in the east. Jiangsu has a total land area of 0.107 million $km^2$, or 1.06% of China's total (Zhang, 2010). Despite its small land area, Jiangsu accounts for 5.8% of total Chinese population and 10.4% of national GDP (National Bureau of Statistics of China, 2013). Jiangsu is one of the most important provinces in China, not least because of its contribution to the national output, but also its industrial structure and the close link with central government institutions. The designation of Coastal Open Cities, Coastal Open Economic Zones, an Open Coastal Belt and new Open Economic Zones in major cities along the Yangtze River allowed the province to exploit its geographic advantages and develop the export-oriented sector (Demurger, et al., 2001).

In 2012, Jiangsu Province ranked second among all Chinese provinces in terms of GDP. In terms of GDP per capita, Jiangsu ranked fourth, after the three Municipalities of Beijing, Shanghai and Tianjin. At CNY 68,347 (or USD 10,827), the GDP per capita of Jiangsu was 78% higher than national average in 2012. Below is a summary of the Province's GDP figures from 1978 to 2012.

**Table 1. Jiangsu Province: GDP and GDP per Capita**

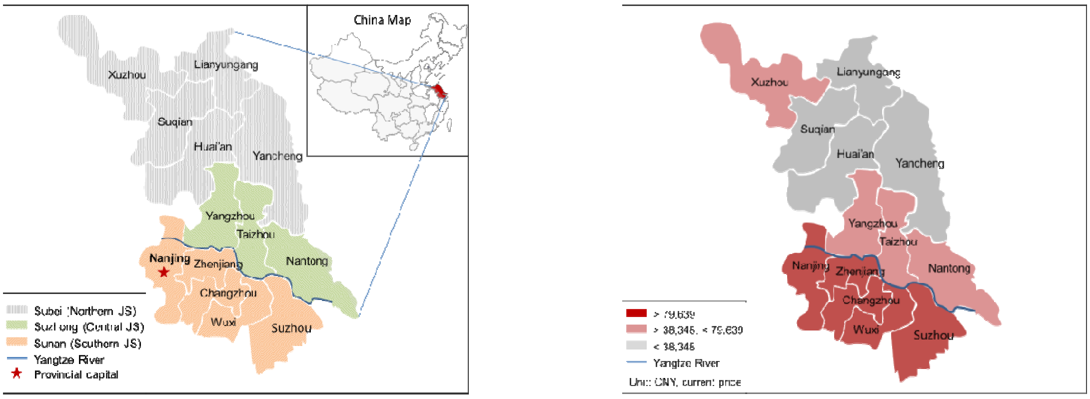
| Year | GDP (100 million CNY) (current prices) | GDP (100 million CNY) (1978 constant price) | GDP (% of national total) | GDP ranking (current prices) | GDP per capita (CNY) | GDP per capita (CNY) (1978 constant price) | GDP per capita (% of national average) | GDP per capita ranking | GDP per capita ranking (excl. Municipalities) |
|---|---|---|---|---|---|---|---|---|---|
| 2012 | 54,058 | 13,753 | 10% | 2 | 68,347 | 17,435 | 178% | 4 | 1 |
| 2010 | 41,426 | 11,256 | 10% | 2 | 52,840 | 14,396 | 176% | 4 | 1 |
| 2000 | 8,554 | 3,251 | 9% | 2 | 11,765 | 4,479 | 150% | 6 | 3 |
| 1990 | 1,417 | 874 | 8% | 3 | 2,109 | 1,304 | 128% | 7 | 4 |
| 1980 | 320 | 292 | 7% | 1 | 541 | 495 | 117% | 6 | 3 |
| 1978 | 249 | 249 | 7% | 2 | 430 | 430 | 113% | 6 | 3 |

Source: National Bureau of Statistics of the People's Republic of China and Jiangsu Provincial Bureau of Statistics

There are 13 prefectures in Jiangsu, with 13 prime cities and 48 counties (or county-level cities). Here we treat a county or county-level city as an entity comparable to the prime city within every prefecture.

The province is officially divided into three regions, namely, Southern Jiangsu (Sunan), Central Jiangsu (Suzhong), and Northern Jiangsu (Subei).

**Figure 1. Maps of Jiangsu Province**




a. Administrative structure

b. GDP per capita disparity in 2012

### *The Pronounced North-South Divide in Jiangsu*

Although Jiangsu is a relatively advanced province, it suffers from striking regional inequality. The most prosperous urban areas in Jiangsu are on the periphery, which are far away from the geographic centre (Shen, 2007). Figure 3-1 (b) shows the difference in GDP per capita at the prefecture level. The first boundary, which is CNY 79,639 or USD 12,616, is the World Bank (n.d.) definition of high income. The second boundary, which is CNY 38,348 or USD 6,075, is China's nominal GDP per capita in 2012. Most Northern cities are below this threshold.

Below is some basic information about Sunan, Suzhong and Subei.

**Table 2: Southern, Central and Northern Jiangsu: Selected Economic Indicators, 2012**

| | South (Sunan) | | Central (Suzhong) | | North (Subei) | |
|---|---|---|---|---|---|---|
| | | % of JS | | % of JS | | % of JS |
| Population (m) | 33 | 42% | 16 | 21% | 30 | 38% |
| Employment (m) | 20 | 42% | 10 | 21% | 17 | 36% |
| Area of land (sq km) | 27,921 | 27% | 20,379 | 20% | 54,473 | 53% |
| Urbanisation rate (%) | 73% | - | 59% | - | 55% | - |
| GDP (CNY billion) | 3,338 | 60% | 1,019 | 18% | 1,218 | 22% |
| GDP per capita (CNY) | 101,370 | 148% | 62,208 | 91% | 40,914 | 60% |
| FDI (US$ billion) | 23 | 64% | 6 | 16% | 7 | 20% |
| Fixed asset investment (CNY billion) | 17,401 | 55% | 6,125 | 19% | 8,181 | 26% |

As can be seen from Table 3-2, with only 27% of total land area and 42% of total population, Sunan contributed approximately 60% to Jiangsu's GDP and attracted 64% of total foreign direct investment in 2012. Per capita GDP of Sunan is 48% higher than the provincial average, far ahead of that of Suzhong and Subei. Another striking fact from the above table is that Subei only contributed 22% to Jiangsu's GDP and attracted only 20% of total FDI, despite 38% of total population and 53% of total land area. Central and Northern Jiangsu lag behind in terms of urbanisation rate, per capita GDP level, FDI, and fixed asset investment. Throughout much of the post-1978 period, Sunan outperformed Suzhong and Subei in almost all of the above-mentioning fields. Such a persistent disparity indicates that some deep-rooted causes, such as educational attainment and infrastructure provision, are responsible.

***Regional Policies in Jiangsu Province from 1978 to 2012***

Three factors are of utmost importance for the research into the regional inequality in Jiangsu. These factors are: (1) the development of the rural industrial sector or TVEs; (2) foreign direct investments; (3) government investments in education and infrastructure.

First, a series of reformist policies started to target the township and village industrial sector in the mid-1980s. While the Jiangsu government was committed to stimulating the rural economy across all regions, a substantial part of the growth in TVE output has been disproportionately concentrated in Sunan during 1985-89 (Rozelle, 1994). Shen and Ma (2005), in a study on the rural industrial sector in Sunan, find that the rise of collectively-owned TVEs in the 1980s and privatisation of TVEs in the 1990s significantly contributed to the Sunan economic growth. In the research on the linkage between regional disparities and the rural industrial sector in Jiangsu, Rozelle (1994) finds that TVE movement during the 1980s has led to a higher level of disparity, and the TVE sector explained on average 80% of inter-township disparity. There was a trend that the disparity was growing more severe, and government policies that favoured rural industrial development ended up with more serious distributional issues (Rozelle, 1994).

Shen (2007) considers that low levels of industrialisation and limited number of wholly foreign owned enterprises are impeding the growth of Subei, compared with Sunan and Suzhong. The reform policies have benefited the development of TVEs in Sunan cities and provided better conditions for foreign investment. Wei and Kim (2002) also show that agglomeration economies and FDI are important determinants of uneven growth across counties in Jiangsu.

Long and Ng (2001) believe that preferential policies and rapid growth of the non-state economic sector after 1978 increased the divisions within the Province. Decentralisation of the fiscal system means the state and provincial governments have less power to redistribute resources to the less well-off regions within Jiangsu. Wei and Kim (2002) believe that Sunan has received considerable preferences in reform policies, and is more active in initiating local policies to stimulate growth.

Regional policies in Jiangsu Province have been through three stages, from active intervention to maturation and enhancement (Su & Gao, 2009). It is pointed out that during much of the 1980s and 1990s period, the government lacked a strategic plan to close the development gap, but rather, implemented piecemeal solutions that only focused on certain aspects of the inequality (Su &Gao, 2009; Zhou, et al., 2009). Regional disparity became more striking between 1984 and 1993 (Su & Gao, 2009).

Between 2004 and 2005, core regional policies were developed by the government. The most important policy instrument is to accelerate industry transfer from the South to North. The Provincial Document (2005) No.86 outlined the guiding principle of industry transfer, requiring that ‘significant projects’ be located in Subei first, before other regions were considered. Most importantly, as an incentive for local authorities in Sunan to participate in industry transfer projects, the document required that tax revenues generated by relocated industries be shared between partner local authorities (Shen, 2007). The result of such incentives was encouraging: in 2006, total output of relocated industries amounted to CNY 70 billion, or equivalent to 20% - 30% of total output of labour-intensive industries in Sunan (Shen, 2007).The provincial government has had a clearer picture of its roles in regional development, which is promoting growth along three main corridors - high-tech industries along the Shanghai-Nanjing corridor (Sunan), basic industries along the Yangtze River (Suzhong), and processing industries along the Longhai Railway (Subei) (Zhang, 2010).Under the 12th Five-Year Plan (2011-2015) framework, the Jiangsu government has published two official documents regarding socio-economic development in Suzhong and Subei between 2012 and 2013(Jiangsu Provincial Government, 2011; Jiangsu Provincial Government Office, 2013).

## 4. Testing Neoclassical Growth Theory

In recent years, based on the neoclassical paradigm, Barro and Sala-i-Martin (1991) and Mankiw *et al*. (1992) find that the one-sector Solow model can be used to explain the growth experience of around 100 advanced and developing countries. The productivity growth will be faster if the region has a capital-labour ratio that is much below its steady-state value. The key assumption of the theory is constant returns to scale and diminishing returns to factors of production, which leads to the prediction of convergence.

Barro and Sala-i-Martin (1991) illustrate two concepts of convergence, one being β-convergence and the other being σ-convergence. β-convergenceis related to economies with their capital/labour ratio below their steady state growing faster than those with their capital/labour at their steady-state level, and σ-convergence happens when the cross-sectional dispersion of per capita income falls over time (Young, et al., 2008; Barro & Sala-i-Martin, 1991). As Young, Higgins and Levy (2008) and Barro and Sala-i-Martin (1991) point out, β-convergence does not imply σ-convergence, as the former focuses on the rate of the 'catch-up' process, while the latter looks at the evolution of distribution of per capita income. When the growth rate of a country or region decreases as it is closer to its steady state, the process is called absolute convergence. If economies experience β-convergence but conditional on other variables such as differences in the investment/output ratio, there is conditional convergence. It should also be noted that given estimates for the parameters of the model disequilibrium states can be persistent for decades.

The model in Barro and Sala-i-Martin (1991) uses an implied conditional β-convergence empirical framework. This is also referred to as the augmented Solow model. For given steady-state per capita output growth rate and outputper effective worker, the lower the initial per capita output, an economy's per capita output will grow faster (Barro & Sala-i-Martin, 1991). The classical Barro-type equation used in the regression analysis in Sala-i-Martin (1996b) is:

$$\frac{1}{T}\log\left(P_{\mathrm{i,t+T}}/P_{i,t}\right) = \alpha - \left(\frac{1-e^{-\beta T}}{T}\right)\cdot\log\left(P_{i,t}\right) + other\ controlling\ variables \qquad (6)$$

where $y_{i,t}$ is per capita income in region $i$ at time $t$, $T$ is the length of the time interval, $\beta$ is the speed of convergence. "Other variables" include exogenous structural variables and stochastic residuals.

A strong negative correlation is found between the growth of per capita income and the initial level of per capita income over the long run in the US, but the convergence is at a very slow rate (Barro & Sala-i-Martin, 1991). A more general finding is that regional convergence of per capita income has been fairly slow in the industrialised economies (Sala-i-Martin, 1996a). Furthermore, it is found that regional convergence is evident in some countries, such as Sweden, and nearly nonexistent in others, including Austria and Greece (Armstrong & Taylor, 2000). In theory, if the degree of labour and capital mobility is higher, β will be greater. This implies that the 'catch-up' process is possibly faster for regions within a country than for across countries (Barro & Sala-i-Martin, 1991). Also, compared with advanced economies, developing countries may have a relatively high convergence rate. For example, Wei *et al.,* (in Armstrong & Taylor, 2000) finds a dramatic convergence rate of 13% across Chinese provinces between 1986 and 1995. However, Wei and Kim (2002), in their research of the inter-county inequality in Jiangsu Province, test β-convergence using gross value of industrial and agricultural output per capita, but find no evidence for β-convergence and long-term convergence. It should be noted, however, convergence in per capita output may not be solely due to economic forces, and political factors may also be relevant.

In this paper, the regression analysis tests for convergence in Jiangsu, and explains factors leading to the persistent disparity. The dependent variable is the productivity growth rates (exponential growth rate of GDP per person employed) of the provinces cities. The test for conditional convergence requires that the level of productivity at the beginning of the period to be included in the regression model. If productivity growth rates are negatively affected by the initial level of productivity and the coefficient is statistically significant, then there is evidence of a potential convergence process. In this research, the initial productivity figures are expressed as natural logarithms, so that it will better fit the linear regression model and this is consistent with the underlying neoclassical theory.

Other variables controlled for include foreign direct investment, fixed assets investment, the infrastructure expenditure (as percentage of the public spending) and the output of township enterprises expressed as a share of the output value of total industry. These variables, suggested by the literature, focus on different causes of divergent growth rates. On the one hand, fixed assets investment tests for whether investments in TVE are more value-for-money, and whether TVEs are more productive than state-owned enterprises (Wei & Kim, 2002). On the other hand, the share of TVE in total industrial output examines whether a city with a significant rural industrial sector grows faster. If Wei and Kim (2002) are correct, then productivity growth rates should be positively correlated with FAI of the TVEs, suggesting that the non-state sector was more efficient and productive. The latter relationship is less clear, because intuitively it is not always true that a prime city with a small rural industrial sector would grow slower than some county-level cities heavily reliant on the TVE sector.

FDI is used to analyse the degree of openness of the city to international conditions. As can be seen from previous discussions, international capital favours Southern Jiangsu more than the Central and Northern regions from 1978 onwards. Policy factors are taken into consideration. Preferential policies have been criticised as one source of regional disparity, but these assertions are rarely based on empirical results. Some researchers have used the number of coastal open zones and open areas as a proxy for preferential policies (for example, Demurger, *et al.,* 2001). However, such data are not available. In this study, infrastructure and education expenditures are included, which partly reflect the policy preferences of the provincial government and local authorities. Education expenditure measures the proportion of government spending on education in total fiscal spending, and infrastructure expenditure is the proportion of government spending on infrastructure in total government spending. They also take into account the importance of human capital and infrastructure. Equation (7) is the estimating equation. Geographical dummies are included to test whether the regional location of the city has any influence over the inter-city growth disparity.

$$p_i = \alpha + \beta lnP_{0_i} + \gamma X_i + \delta south_i + \theta central_i + \varepsilon_i \qquad (7)$$

where $p_i$ is the growth rate of productivity of the ith city, $ln\,P_{0_i}$ is the level of productivity at the beginning of the period, *X* represents the log of the other controls (averages over the period). The dummy variable $south_i$ is equal to 1 for Southern Jiangsu cities, and 0 for all other cities. Likewise, $central_i$ is 1 for the Central cities.

***Estimation Results***

One problem with the estimation using spatial data is the complication posed by the presence of spatial autocorrelation. This can result from predominantly two causes, although there others (for a full discussion, see Angeriz *et al.,* 2008). The first is the spatial error model or what is known as the spatial nuisance autocorrelation because it does not have any economic implications. Let us suppose that in the general case the estimating equation is given by $y = \boldsymbol{X}\delta + \varepsilon$ where *y* is the dependent variable, $\boldsymbol{X}$ is a vector of regressors and ε is the error term. Spatial autocorrelation arises because the error terms of adjacent regions are correlated and consequently $\varepsilon = \xi \boldsymbol{W}\varepsilon + \mu$, where $\boldsymbol{W}$ is a weights matrix (taking, in the simplest case, a value of 1 when two regions are contiguous and 0 when they are not).[1] This arises from the non-economic definitions of regional boundaries. That is to say, the growth rates of the variables of adjacent regions, such as productivity growth, are likely to be highly correlated purely because of the way regional boundaries are delineated and are not random draws. Thus, the error terms of adjacent regions, arising from omitted variables or measurement errors, are likely to be correlated.

[1] There are more complicated matrixes involving distance decay functions between the various cities. This is discussed below.

The other common form of spatial autocorrelation is given by the spatial lag model by $y = X\delta + \eta Wy + \varepsilon$. This is where there are spillover effects and the dependent variable of a region (say, productivity growth) has a positive effect on the productivity growth of a neighbouring region. The use of Lagrange Multiplier tests is used to test whether or not spatial autocorrelation exits and jointly whether the spatial error model or the spatial lag model is to be preferred. However, they are of low power with respect to the last. As the Solow growth model gives no theoretical rational for spillovers (the rate of technical change is a pure public good), any spatial autocorrelation is likely to be of the nuisance variety. This means that the estimates are inefficient, but unbiased and this must be borne in mind when interpreting the results. However, Moran's I suggests that there is no statistically significant spatial autocorrelation in the estimates of the Solow growth model discussed below and so the results reported below are for OLS and IV, the latter to account for the possibility of simultaneous equation bias.

In testing conditional convergence across cities using the Barro-type framework, it is better to analyse the longest period where possible. Therefore, data from 1996 to 2012 are used to run the regression model for total city output (GDP) and data from 1999-2012 for industry. As the data show the existence of a sharp break in the middle of both time periods (see Appendix 2), we split the time period into the periods 1996-2004 and 2005-2012 (GDP) and 1999-2005 and 2006-2012 ( industry), and also estimate the equations before and after the structural break.

Both the OLS and the IV[2] regression methods are employed to estimate the growth equation. Data are from Jiangsu Statistical Yearbooks 1997- 2013. To calculate the real GDP per person employed growth rates, GDP in current prices for each city are converted to the 1996 constant price, using the China GDP deflator[3].

The results of the regression analysis are presented in Table 3. They indicate that there is strong evidence of convergence across cities over the whole period, since the coefficient of the initial (log) level of productivity is negative and statistically significant for both GDP and industry. Considering the break, it can be seen that both for GDP and for industry, there is no evidence of convergence up until 2004 and 2005 respectively, and convergence subsequently. This is in accord with Wei and Kim's (2002) finding that there was no evidence of convergence in Jiangsu in the early 1990s. It is only from about 2005 that there is evidence of convergence, which may be the result of policy, discussed above.

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[2] The instruments are defined following the Durbin's ranking method, which involves ranking each value of a variable from 1 to *n* and then using the ranks as instruments. This was originally developed to cope with measurement problems but the ranks act as a good instrument for more general endogeneity problems.
[3]Source: EconStats, *World Economic Outlook.* Accessed online: http://www.econstats.com/weo/CCHN.htm

Geographical dummies are included to estimate within-region convergence. Regional factors are important in explaining convergence. Indeed, the results show that the convergence of productivity across cities is more evident *within* each region than *across* regions. Both dummy variables are highly significant and have a positive impact on the productivity growth rate. [This suggests that cities in Southern and Central regions had different and faster exogenous productivity growth rates compared with the Northern cities. This is in line with the reality that Southern Jiangsu cities grew fastest, and Northern cities were lagging behind during 1996-2012.

As far as the other regressors are concerned, an increase in the proportion of fixed assets investment in TVEs is associated with a small increase in the productivity growth rate, conditioning the other explanatory factors. This is consistent with Rozelle's (1994) finding that a significant percentage of the inequality can be explained by the growing rural industrial sector. Interestingly, the share of township enterprises output at the beginning of the period has a positive impact on the productivity growth. FDI and infrastructure expenditure are never statistically significant. This contradicts Demurger' s conclusion that infrastructure level is important in attracting investment and leading to higher growth rate. The contradiction might be attributable to methodological issues, because in our analysis, a different proxy for the effect of the government's infrastructure policy is used.

The results show that there is evidence of slow conditional convergence across cities in the second period. Higher levels of fixed asset investment in the rural industrial sector have been associated with higher growth rates. Being located in the South is also associated with faster economic growth, which could partly be explained by the proximity to Shanghai, the financial hub. The regression results also support Demurger's (2000) doubt over the role of preferential policies in contributing to regional disparities in China at least prior to 2005/2006, while challenging Fan's (1997) assertions.

In summary, there is evidence of a relatively strong convergence process in Jiangsu from 1996 (1999) to 2012, but this is almost entirely due to convergence in the later period, from 2005 (2006) to 2012. However, the assumption of constant returns to scale is difficult to justify in the context of regional or city economies, given the likely prevalence of agglomeration economies or increasing returns to scale broadly defined.

**Table 3. Neoclassical convergence model. OLS and IV regressions.**

| | Dependent Variable: *Productivity Growth Rate* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total GDP | | | | | | Industry | | | | | |
| | 1996-2012 | | 1996-2004 | | 2005-2012 | | 1999-2012 | | 1999-2005 | | 2006-2012 | |
| | OLS | IV | OLS | IV | OLS | IV | OLS | IV | OLS | IV | OLS | IV |
| $lnP_0$ | -.0232***<br>(-3.75) | -.0221***<br>(-3.33) | -.0003<br>(-0.03) | -.0093<br>(-0.84) | -.0579***<br>(-7.03) | -.0608***<br>(-7.03) | -.0420***<br>(-4.30) | -.0424**<br>(-4.40) | -.0057<br>(-0.40) | -.0046<br>(-0.32) | -.0852***<br>(-6.39) | -.0868***<br>(-6.41) |
| *lnFDI* | -.0054<br>(-1.44) | -.0065<br>(-1.48) | -.0033<br>(-0.55) | .0043<br>(0.60) | -.0106*<br>(-1.96) | -.0071<br>(-1.13) | | | | | | |
| *lnFAI* | .0154**<br>(2.16) | .0162*<br>(1.94) | .0475***<br>(2.89) | .0296*<br>(1.72) | .0114<br>(1.13) | .0106<br>(1.00) | | | | | | |
| *lnIE* | -.0000<br>(-0.02) | -.0004<br>(-0.16) | .0002<br>(0.07) | .0023<br>(0.57) | -.0025<br>(-0.69) | -.0005<br>(-0.13) | .0022<br>(0.48) | .0027<br>(0.59) | .0081<br>(1.35) | .0069<br>(1.04) | -.0003<br>(-0.06) | .0024<br>(0.43) |
| $lnTE_0$ | .0102**<br>(2.50) | .0103**<br>(2.40) | .0218**<br>(2.49) | .0166*<br>(1.94) | | | | | | | | |
| *South* | .0206***<br>(4.09) | .0211***<br>(4.22) | .0146<br>(1.21) | .0123<br>(0.98) | .0379***<br>(3.30) | .0380***<br>(3.41) | .0170*<br>(1.97) | .0170*<br>(1.96) | .0377**<br>(2.33) | .0379**<br>(2.34) | .0190<br>(1.08) | .0190<br>(1.09) |
| *Central* | .0184***<br>(4.60) | .0189***<br>(4.73) | .0095<br>(1.26) | .0079<br>(1.05) | .0317***<br>(3.45) | .0301***<br>(3.40) | .0147**<br>(2.40) | .0147**<br>(2.41) | .0419***<br>(2.88) | .0417***<br>(2.86) | .0081<br>(0.66) | .0080<br>(0.67) |
| *constant* | .0690***<br>(5.00) | .3310***<br>(4.48) | .1900*<br>(1.83) | .2806**<br>(2.43) | .6961***<br>(6.87) | .7441***<br>(6.96) | .5397***<br>(4.91) | .5460***<br>(5.04) | .1636<br>(1.06) | .1482<br>(0.93) | 1.0480***<br>(7.14) | 1.0754***<br>(7.16) |
| N | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| F test p-value | 0.0000 | 0.0000 | 0.0519 | 0.0676 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0196 | 0.0269 | 0.0000 | 0.0000 |
| R-squared | 0.6224 | 0.6217 | 0.2930 | 0.2638 | 0.7363 | 0.7332 | 0.4023 | 0.4021 | 0.1852 | 0.1848 | 0.5560 | 0.5538 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels.
The dependent variable is the exponential growth rate of productivity over the 1996-2012 periods in case of total GDP and over the 1999-2012 periods for secondary industry because of missing data. The study of the standard deviation of the level of productivity reveals divergence up until 2004 for total GDP and 2005 for secondary industry, then convergence subsequently. To study the break, the sample is split in two periods.
All the regressors are expressed in logarithmic terms. $lnP_0$ is the log-level of productivity at the beginning of the period (logarithm of GDP per person employed).
*ln FDI*, *lnFAI* and *lnIE* are the logged averages over the periods of the Foreign Direct Investments, the Fixed Assets Investments (both expressed as percentages of GDP) and the public infrastructure expenditure (expressed as a percentage of the public spending). $lnTE_0$ is the logged output of the township enterprises expressed as a share of the output value of total industry. Due to missing data, it is expressed as the average of the 1996 and 1997 observations. Population is the number of persons at the beginning of the period. South and Central are geographical intercept dummies.
Preliminary specifications included also the public education expenditure (as a percentage of the public spending). However, to construct a more reliable model, this regressor was dropped as it is strongly correlated with the level of productivity at the beginning of the period (degree of correlation greater than 0.70 and VIF greater than 5).
As for industry, the controls related to total GDP (FDI and FAI) are dropped.
Figures in parenthesis are the t-statistics. OLS and IV are ordinary least squares and instrumental variables (GMM) regressions. Where necessary, the regressions are controlled for heteroskedasticity. In case of IV regressions, the instruments are defined following the Durbin's ranking method, which involves ranking each value of a variable from 1 to *n* and then using the ranks as instruments.
Diagnostic tests (Moran's I, Lagrange Multiplier, Robust Lagrange Multiplier) reveal there is no spatial dependence in the data.

## 5. Testing Kaldor's Growth Laws

***The First Law***

Kaldor (1966, 1975) proposed three empirical laws, or regularities, to explain economic growth. We shall concentrate on his first and second (or the Verdoorn) laws.[4] The first law is that there is a close relationship between the growth of total output and that of industry, or manufacturing, with the latter causing the former. This is relationship is given by:

$$q_{GDP} = c + b_1 q_{IND} \quad (8)$$

Because GDP definitionally includes industry as a component, this equation may be re-specified as:

$$q_{ROE} = c + b_2 q_{IND} \quad (9)$$

where ROE denotes the rest of the economy, i.e., GDP less industrial output. What is the interpretation of this relationship? As we have seen, a key determinant of the growth of output is that of exports, and these are largely manufactured products. This is the basis of the export-led growth model, or export-base theory, of regional economic activity. Hence, a faster growth of exports leads to a faster growth of industrial output which, in turn, will lead to a faster growth of the rest of the economy. See Thirlwall *et al*., (2014)

As the standard diagnostic tests reject the null hypothesis of spatial autocorrelation, Table 4 reports the OLS and IV estimates of equation (9). The data are the average growth rates over the whole of the period.

It can be seen that the coefficient of the growth a city's industrial output is statistically significant and an increase in the latter by one-percentage point increases the growth of the rest of the city output by about 0.25 percentage points. This confirms other estimates of the first law (Thirlwall *et al.,* 2014). The regional intercept dummies show that the cities in the Southern province have an exogenous growth of the rest of their economies that is statistically significantly greater than the other two provinces.

We considered two further specification of the first law. The first was to estimate equation (9) using annual data in a panel auto-regressive model with spatial auto-regressive disturbances and a two-way fixed effects estimator. The estimation controlled for spatial autocorrelation although this was statistically insignificant.

The coefficient of 0.3 was slightly higher than that obtained using average growth rates and the t - statistic was higher (Table 5).

The second specification is of the first law in log-level form (equation (10)), from which the growth rate specification can be derived by differentiating the function with respect to time.

$$lnQ_{ROE} = c + b_3 lnQ_{IND} \quad (10)$$

[4] The third law is merely a combination of the first two law and an identity and contains no empirical evidence beyond that given by the first two laws (McCombie, 1985).

The estimation procedure was the same as before, with annual data in a spatial panel model. This time there was statistically significant spatial autocorrelation. The coefficient was 0.25 and statistically significant, again similar to the previous results and not refuting Kaldor's first law.

**Table 4. Kaldor's First Law. OLS and IV regressions.**

| | Dependent variable: *Growth of Non-Industry* ($q_{ROE}$) | |
|---|---|---|
| | OLS | IV |
| $q_{IND}$ | .2575**<br>(2.50) | .2398**<br>(2.13) |
| *South* | .0248***<br>(4.27) | .0243***<br>(4.20) |
| *Central* | .0064<br>(1.07) | .0062<br>(1.04) |
| *constant* | .0830**<br>(4.71) | .0858**<br>(4.53) |
| N | 61 | 61 |
| F test p-value | 0.0008 | 0.0009 |
| R-squared | 0.3033 | 0.3028 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels. Period is 1996-2012 period.
South and Central are geographical intercept dummies.
Figures in brackets are the t-statistics. OLS and IV are ordinary least squares and instrumental variables (GMM) regressions. These regressions are controlled for heteroskedasticity. In case of IV regressions, the instruments are defined following the Durbin's ranking method, which involves ranking each value of a variable from 1 to *n* and then using the ranks as instruments.
Diagnostic tests (Moran's I, Lagrange Multiplier, Robust Lagrange Multiplier) reveal there is no spatial dependence in the data.

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**Table 5. Static and Dynamic Kaldor's First Law Spatial Panel Autocorrelation Model[§].**

| | Dependent Variable: $\ln Q_{ROE}$ | Dependent Variable: $q_{ROE}$ |
|---|---|---|
| $\ln Q_{IND}$ | .2548***<br>(2.97) | |
| $q_{IND}$ | | .3030***<br>(6.86) |
| $\rho$ | .3452**<br>(1.96) | .1112<br>(0.48) |
| $\lambda$ | .5626**<br>(4.45) | .1682<br>(1.35) |
| *Time Dummies* | yes | yes |
| N | 1037 | 976 |
| Number of cities | 61 | 61 |
| Panel length | 17 | 16 |
| R-squared<br>Within<br>Between<br>Overall | <br>0.9511<br>0.8789<br>0.8979 | <br>0.2643<br>0.0185<br>0.2395 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels. Period is 1996-2012.
[§]Spatial panel auto-regressive model with spatially auto-regressive disturbances (two-way fixed effects).
$\rho$ is the spatial autocorrelation coefficient; $\lambda$ is the spatial error term coefficient.
The figures in brackets are the t-statistics. All the estimation results are controlled for heteroskedasticity.

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### *The Second, or Verdoorn's, Law*

The Solow model assumes disembodied exogenous technical change, perfectly competitive markets and, for our purposes, most importantly constant returns to scale. However, it is usually assumed that regional economies are subject to increasing returns. As Paul Krugman points out, why else would cities exist given transport costs, if it were not for increasing returns to scale and agglomeration economies? As we have seen above, in contrast to the neoclassical growth model, the cumulative causation emphasizes the role of increasing returns to scale which provides a powerful force for regional (and national) divergences in productivity growth rates (Myrdal, 1957, Kaldor, 1970). It is this which gives rise to the trade-off between regional equity and efficiency, emphasized by the World Bank (2007). The cumulative causation model is essentially a demand-oriented explanation of regional growth disparities. A faster growth of output increases that of productivity, which *ceteris paribus*, improves the price competitiveness of the region through mark-up pricing. This, in turn leads to a faster growth of exports which in turn increases the region's output growth through the Hicks (dynamic) super-multiplier. Whether productivity growth converges to a steady-state, which may differ between regions or is explosive, but which is eventually constrained by the supply side (i.e., by the limits to the rate of migration and capital accumulation) depends upon the parameters of the model (Dixon and Thirlwall, 1995).

At the heart of the cumulative causation model is the Verdoorn law. In its simplest specification, this is the linear relationship between productivity and output growth. The law may be derived, for city *j,* from a Cobb-Douglas production function as follows:

$$Q_j = Ae^{\lambda t}K_j^{\alpha}L_j^{\beta} \qquad (11)$$

where $Q, K$, and $L$ are the levels of output, capital, and labour respectively, $\lambda$ is the rate of technological progress, and $\alpha$ and $\beta$ are the output elasticities of capital and labour. $A$ is a constant and represents the level of technology. It is assumed that $\alpha + \beta = \gamma(\alpha' + (1-\alpha'))$, where $\gamma$ is a measure of the degree of static returns to scale. $\alpha'$ is assumed to be equal to capital's share in value added.

A key assumption of the Verdoorn law is that the rate of technological progress is largely endogenously determined by growth of the weighted factor inputs which may be expressed as:

$$\lambda = \lambda' + \eta(\alpha k_j + \beta l_j) \qquad (12)$$

where $\eta$ is the elasticity of induced technical progress with respect to the weighted growth of the inputs and $k$ and $l$ are the growth rates of capital and labour, respectively. $\lambda'$ is the rate of exogenous technical progress.

Taking logarithms of equation (11), differentiating with respect to time, using equation (12) and rearranging gives:

$$q_j = \lambda' + (\eta + \gamma)(\alpha' k_j + (1 - \alpha'))l_j \qquad (13)$$

where $v = (\eta + \gamma)$ is an encompassing measure of the degree of dynamic and static returns to scale. This is assumed to be constant across regions. Re-arranging equation (13) yields the dynamic Verdoorn law:

$$p_j = \frac{\lambda}{v(1-\alpha')} + \left(1 - \frac{1}{v(1-\alpha')}\right) q_j + \frac{\alpha\prime}{(1-\alpha')} k_j \qquad (14)$$

The simplest specification of the Verdoorn law omits the growth of the capital stock (for lack of data) and is given by $p = a_0 + b_1 q$ where $b_1$ is the Verdoorn coefficient and usually takes a value of 0.5. This implies that a one percentage point increase in output growth is associated with a half percentage point increase in productivity growth and half a percentage point increase in employment growth. If there were constant returns to scale, the Verdoorn coefficient would be zero and a one percentage point increase in output (holding the rate of technical progress constant) would require an increase in employment of an equal magnitude

The stylized fact that over a period of several years, the growth of the capital stock on average is equal to the growth of output, is sometimes assumed. In these circumstances, the Verdoorn coefficient is equal to:

$$\frac{v(1-\alpha')-1}{v(1-\alpha')} \qquad (15)$$

In practice, as we noted above, $\alpha'$ is taken to be equal in value to capital's factor share ($a$). In this case, a Verdoorn coefficient of one half is equal to encompassing increasing returns to scale, which includes induced technical change.

Alternatively, the gross investment-output ratio is sometimes used as a proxy for the growth of the capital stock. Scott (1982) in his *New View of Economic Growth* argues that theoretically the gross investment-output is the correct measure of the contribution of the growth of capital. The usual measure of the capital stock is calculated by using *net* investment and the perpetual inventory method. If Scott's argument is accepted then the Verdoorn law cannot be integrated into a conventional Cobb-Douglas production function, which is more in accord with Kaldor's (1958) argument that it makes no sense to differentiate between movements along a production function and shifts of the production function.[5]

[5] Kaldor (1957) attempted to formally model this with his technical progress function. Unfortunately, if this is linearized around its steady state rate of growth it can be integrated to give a conventional Cobb-Douglas production function (Black, 1962). If Scott's argument is accepted, this cannot be the case.

In the Verdoorn law, output growth is assumed to be the regressor, because with factor mobility, etc., it is assumed that growth is primarily determined by demand factors (Thirlwall, 1980).[6] These include, for example, the structure of city output. Does, for example, a city have an above-average share of fast growing hi-tech industries and financial services or is production concentrated in, say, declining heavy industry?

Early work by McCombie and de Ridder (1984) and McCombie (1985) estimating the law and explicitly including the growth of the capital stock found evidence of substantial increasing returns to scale using cross-regional US state data. Hansen and Zhang (1996) confirmed the relationship for the Chinese provinces, and León-Ledesma (1999, 2000) for the Spanish regions. Harris and Lau (1998) and Harris and Liu (1999) have also confirmed Verdoorn's law using time-series data for the UK regions and a large sample of countries, respectively.

Verdoorn's law suggests that productivity growth is attributed largely to output growth. However, the new economic geography and growth theory suggests that there are other additional determinants of productivity growth. These include technological diffusion from high to low technology regions (Fingleton and McCombie, 1998; McCombie, 1982),[7] production density within a region (Baldwin and Martin, 2004), the degree of production specialisation (Arrow, 1962; Marshall, 1920; Porter, 1998; Romer, 1986) and diversity (Jacobs, 1970). Angeriz *et al*. (2008, 2009) were one of the first to estimate the augmented dynamic Verdoorn law that controls for the above determinants of localised productivity growth. Unfortunately, we do not have the data to estimate an augmented Verdoorn law and so have to be content with the simple specification.

There is an implicit assumption that all cities have access to the same technology under the initial Verdoorn law framework (see Kaldor 1966). The reality is, however, that lagging cities may be backward in terms of their level of technology. Therefore, the resultant productivity growth may be attributable to a catch-up or convergence process due to the diffusion of new technology from the more to the less technologically developed cities. A common practice in testing the technological diffusion is to include the log-level of GDP per capita, or the ratio of the level of GDP per capita to the technological leader (Fingleton & McCombie, 1998). In this study, $lnP_o$, the logarithm of the initial per capita GDP level, is used as a proxy for technical diffusion. Unlike in the neoclassical approach, $lnP_o$ in the Verdoorn law framework captures the effect of diffusion of innovations, rather than the faster growth in the capital/labour ratio if a city is below its steady-state level. If we are using industrial data then $lnP_0$ is the initial level of industrial productivity.

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[6] As Thirlwall, (1980, p.420) puts it: "regional growth is demand determined for the obvious reason that no region's growth rate can be constrained by supply when factors of production are freely mobile. For a region in which capital and labour are highly mobile in and out, growth must be demand determined. If the demand for a region's output is strong, labour and capital will migrate to the region to the benefit of that region and to the detriment of others. Supply adjusts to demand. We cannot return to the pre-Keynesian view that demand adjusts to supply. If we could, the solution to any region's lagging growth rate would be for it to save more and breed more!".

[7] This is ruled out by assumption in the Solow growth model.

The Solow model assumes that all cities, regions or countries have access to the same technology and so disparities in productivity growth rates are due solely to the degree of divergence of the region from its steady-state growth rate. It is the latter that is approximated by the log-level of the initial productivity. Consequently, the same variable is capturing to very different effects in the two models. Fingleton and McCombie (1998) believe that spatial differences in technology would be largely at the international level and that these effects should be captured by the national dummies. Likewise, in this study, technological differences might be at the inter-regional level, so that regional dummies would help to capture the spatial effects. The $\ln P_0$ would therefore capture technological diffusion abstracting from this.

***An Alternative Explanation of the Verdoorn Law*** [8]

So far in this paper, we have followed the traditional approach in deriving the Verdoorn law from an aggregate production function, specifically a Cobb-Douglas production function, which allows for the possibility of increasing returns to scale. There is, however, a fundamental problem with the aggregate production function, which, to the extent that the Verdoorn Law is derived from it, also affects this relationship. The aggregation problems resulting from the summing of micro-production functions to give an aggregate production function are so severe that Fisher (1992, 2005) concluded that the aggregate production function cannot exist, *even as an approximation*. The standard instrumentalist methodological defence is that all theory involves approximations and the aggregate production function works, in the sense that it gives close statistical fits to the data with the estimated output elasticities of labour and capital often close to the observed factor shares. However, the estimation of aggregate production functions has to use constant-price value (or monetary) data for output and capital, rather than physical units in which the inputs and outputs theoretically should be measured (Ferguson, 1971). This is because the production function is essentially an engineering, or technological, concept. This is not a compelling defence of the aggregate production function, as the existence of an underlying accounting identity precludes giving these estimation results *any* behavioural interpretation.

As the argument has been discussed in detail in the book by Felipe and McCombie (2013) and its application to spatial economics described by Felipe and McCombie (2010), we can be brief. We confine ourselves to the case of the Cobb-Douglas production function, although the argument applies to *any* aggregate production function. The accounting identity may be written as:

$$VA \equiv WL + RJ \tag{16}$$

[8] This draws on McCombie and Spreafico (2015).

where *VA* is value added measured in constant prices, *W* is the real wage rate, *L* is again the numbers employed, *R* is the rate of profit and *J* is the constant price capital stock.[9] Differentiating the identity and expressing it in growth rates gives:

$$va_t \equiv a_t w_t + (1-a)_t r_t + a_t l_t + (1-a)_t j_t \qquad (17)$$

where the lower case variables *va*, *w*, *r, l* and *j* denote growth rates and *a* and *(1-a)* are labour's and capital's share in value added respectively. It should be emphasised once again that this is merely an identity and has no behavioural implications. If we integrate equation (14) then, at any point in time, the following identity also holds:

$$VA_t \equiv A w_t^{a_t} r_t^{(1-a)_t} L_t^{a_t} J_t^{(1-a)_t} \qquad (18)$$

This is not an approximation to equation (16), but an exact isomorphism.

Let us assume that over time both factor shares and the rate of profit are constant and the real wage rate grows at a constant trend rate. It must be emphasised that nothing in the argument stands or falls by these assumptions, and they are made for expositional ease. The critique still applies in the more general case when they are not made (Felipe and McCombie 2013). Integrating equation (18) gives:

$$VA_t \equiv A e^{\lambda t} L_t^{a_t} J_t^{(1-a)_t} \qquad (19)$$

This is mathematically equivalent to the Cobb-Douglas production function (which does not exist) where, under the usual neoclassical assumptions that factors are paid their marginal product and there is perfect competition and constant returns to scale, the output elasticities equal their factor shares. But it must be emphasised that, apart from the assumptions noted above, equation (19) and its estimation have no behavioural implications.

Equation (19) may be written in terms of growth rates as:

$$va_t = \lambda + a j_t + (1-a) l_t \qquad (20)$$

which is the restricted version of equation (17).

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[9] We use the notation *VA* and *J* to differentiate the constant-price value measures of output and capital from the theoretical physical quantity measures, *Q* and *K*.

Equation (20) is compatible with any form of competition, whether increasing or constant returns to scale prevail and, indeed, even when an aggregate production function does not exist. Estimating the putative aggregate production function in growth rate form as:

$$va_t = c_1 + b_1 j_t + b_2 l_t \tag{21}$$

must give a near, or perfect, statistical fit with the estimates of $b_1$ and $b_2$ equal to the value of the factor shares. The only time when this does not occur is when time-series data are used and $(1\text{-}a)w_t$ (or $ar_t+(1\text{-}a)w_t$ ) is not a constant rate of growth, but has, say, a cyclical component. However, there is nothing in neoclassical production theory that states that the rate of technical progress should be exactly constant over time (Solow, 1957). Consequently, all that is required is a more flexible functional form for the constant to track the weighted growth of the rate of profit and the wage rate to estimate precisely the identity. Thus, the best statistical fit of an 'aggregate production function' must have the output elasticities equal to the factor shares and perhaps erroneously imply constant returns to scale, irrespective of the true degree of returns to scale of the individual production processes.

What then are the implications for the Verdoorn law, which is usually estimated using average growth rates for cross-regional data? From the accounting identity it follows that:

$$ar_{jt} + (1-a)w_{jt} \equiv \lambda_{jt} + 0.va_{ij} \equiv \lambda_{jt} \tag{22}$$

where $j$ denotes the region or city and the growth rates are calculated over a period of several years to exclude the effect of cyclical fluctuations and labour hording. The latter gives rise to a similar short-term relationship between productivity and output growth derived from Okun's law, but this has nothing to do with the existence, or otherwise, of increasing returns to scale.

Let us assume, again, that the rate of profit does not greatly change over time so equation (22) may be written as:

$$w_{jt} \equiv p_{jt} \equiv \lambda'_{jt} + 0.va_{ij} \equiv \lambda'_{jt} \tag{23}$$

where $\lambda_t/(1-a) \equiv \lambda'_j$

In other words, from the accounting identity, the Verdoorn coefficient must take a value of zero, which could be interpreted as indicating the presence of constant returns to scale. However, we know that this must be true as a matter of logic from the underling accounting identity. However, notwithstanding this, the conventional estimation of the Verdoorn law does tell us something about the conditions of production. Recall that the Verdoorn is estimated as:

$$w_{jt} \equiv p_{jt} \equiv c_2 + b_3 a_{ij} \qquad (24)$$

In other words, $c_2$ (which is an estimate of $\lambda$) is assumed to be a constant rate of growth. An estimate of $b_3$ of one half does reflect a behavioural relationship as it implies that a faster growth of output, in this regional context, is associated with a faster growth of the real wage rate (or productivity). However, no inferences can be made about the contributions of the growth of the capital stock or technical progress to productivity growth as this requires the assumption of an underlying aggregate production function. This argument may be most easily demonstrated using a figure.

Figure 2 shows the situation for three regions, where the accounting identity is given by the solid lines and the "Verdoorn coefficient" is zero. However, as we noted the Verdoorn law is usually estimated with a constant intercept. As can be seen from the figure, the results show that a faster growth of output is associated with (and, under this interpretation, causes) a faster growth of the wage rate (or the weighted growth of the wage rate and the rate of profit). In other words, the Verdoorn law is given by the line *ab*. This represents a measure of the growth of the general efficiency of an economy, which is due to either the rate of technical progress (both induced and exogenous), growth of the capital stock or increasing returns to scale or all three.

However, these different sources of growth cannot be empirically separately calculated or theoretically differentiated.

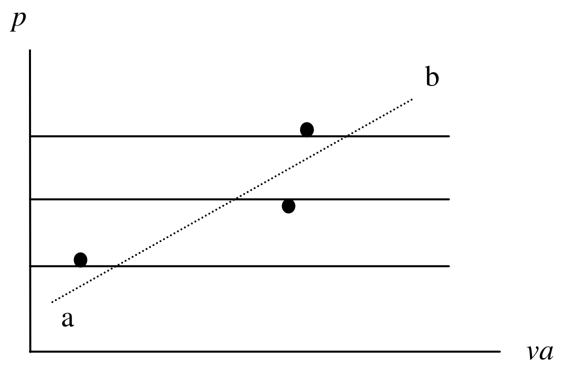


**Figure 2. The Cross-sectional Verdoorn Law**

Ironically, this view of the production process was precisely the position that Kaldor (1958) took. It makes no sense, he argued, to try to differentiate movements *along* the production function from *shifts* of the production function. It is, however, better to interpret the Verdoorn law as simply an aggregate production relationship rather than an aggregate production function, *per se*. There is a further irony in that if estimation techniques are used that allow the constant term to differ between *all* regions, then we know *a priori* that the goodness of fit will be improved and the Verdoorn coefficient will be statistically insignificant. This is because, once again, all that is being estimated is a definitional relationship. The conventional Verdoorn law, as specified above, however is a behavioural relationship in that the estimate of Verdoorn coefficient may take any value. Consequently, the results of the estimates of the Verdoorn law reported in this paper do show that growth proceeds in a cumulative causation manner. A faster growth of output leads to a faster growth of efficiency broadly defined and also real wages. This is true even if the exact interpretation of the Verdoorn law differs from that usually put forward as being derived from an aggregate production function. An implication is that the goodness of fit is not a good demarcation criterion for deciding between the two specifications, as is usually assumed in econometric work. The identity must always win out.

**The Verdoorn Law: Estimation Results**

The results of estimating the degree of increasing returns are shown in Table 6, where in order to minimise the effect of short- run fluctuations between productivity and output growth via the Okun effect, the average growth rates are used over the period 1996-2012 for total GDP and over the period 1999-2012 for industry. Because of labour hoarding, short-run cyclical fluctuations in demand will generate a positive relationship between productivity and output growth, which is known as Okun's law and has nothing to do with whether increasing or constant returns to scale are present. We also provide estimates of the Verdoorn law before and after the structural break identified above. As the usual diagnostics reject the null hypothesis of the presence of spatial autocorrelation, the results reported are the OLS and IV estimates for the 61 cities.

It can be seen that the Verdoorn coefficient is statistically significantly greater than zero in all the periods and for both total output and industry. The values for GDP range from about 0.5 to approximately 0.8 depending upon the time period and the estimation procedure. The estimates for industry are very similar, ranging from roughly 0.4 to 0.8. The controlling variables, namely the logarithms of foreign direct investment; fixed asset formation (both expressed as a share of total output); infrastructure expenditure ( as a proportion of total public spending ) and total population (to capture the impact of city size on productivity growth) are all statistically insignificant. One notable exception is city size (the logarithm of city population) does seem to have a positive effect on industrial productivity growth in the period 2006-2012, although surprisingly not for the earlier period (1999-2005).

These results suggest that the cities exhibit substantial encompassing returns to scale (i.e., resulting from induced technical change, internal economies of scale and agglomeration economies). These results are similar to the results obtained for other data sets, such as the US states, the EU regions and the UK regions. The regional dummies are statistically significant both for total GDP and industry over the whole period with exogenous productivity in the more developed South and the Central regions growing faster than in the North.

The level of productivity at the beginning of the period is also included as a regressor. The rationale for the inclusion of this variable is different from the Solow model. Here, it is assumed that the level of technology differs between the cities and this is captured by the initial level of productivity. It is hypothesised that the less advanced is a city's technology, the lower will be its (log) level of productivity. Generally, but not always, the coefficient of this variable is negative and statistically significant, suggesting that the less technologically advanced cities benefit from the diffusion of innovations from the more advanced cities. The most notable exception is for industry in the second period (1995-2005), which suggests that the gains from the diffusion of innovations may have been exhausted.

The estimated impact of the regional dummies is also positive and statistically significant, and captures regional differences in exogenous productivity growth.

In summary, there is a strong evidence of increasing returns to scale across the Jiangsu cities during the full period 1996 to 2012 (or 1999-2012 if industry is considered). There is also a statistically significant, yet weak, diffusion of innovations, across the 61 cities.

It was suggested above that the use of exponential growth rates averaged over several years minimises the bias due to the short-run fluctuations in productivity. The disadvantage of this procedure is that this greatly reduces the degrees of freedom in the estimation. Consequently, as the growth rates were exceptionally rapid over this period, without any severe fluctuations, we estimated the Verdoorn law using panel estimation methods and annual data. While care must be taken in interpreting these results, we believe it is a useful exercise. This increased the number of observations from 61 to 976 (total GDP ) and 793 (industry). The diagnostics do not now reject the null hypothesis of the presence of spatial autocorrelation and, consequently, the model was estimated using a spatial panel auto-regressive model with spatially auto-regressive disturbances with a two-fixed effects estimator. This estimation procedure controls for both sources of spatial autocorrelation, namely the substantive and nuisance types. The results of the regressions are reported in Table 7, where it can be seen the Verdoorn coefficients are 0.87 (GDP) and 0.87 (industry), provides further confirmation of the presence of substantial encompassing increasing returns to scale.

**Table 6. Dynamic Verdoorn Law. OLS and IV regressions.**

| | Dependent Variable: *Productivity Growth, p* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total GDP | | | | | | Secondary Industry | | | | | |
| | 1996-2012 | | 1996-2004 | | 2005-2012 | | 1999-2012 | | 1999-2005 | | 2006-2012 | |
| | OLS | IV | OLS | IV | OLS | IV | OLS | IV | OLS | IV | OLS | IV |
| *Output growth, q* | .5030*** | .5054*** | .6961*** | .8098*** | .8230*** | .8070*** | .4404*** | .4055*** | .8834*** | .8332*** | .7233*** | .6044*** |
| | (5.65) | (5.77) | (6.86) | (8.51) | (7.96) | (7.04) | (3.15) | (2.80) | (5.22) | (5.31) | (3.64) | (2.91) |
| *ln $P_0$* | -.0185*** | -.0203*** | -.0123 | -.0244** | -.0363*** | -.0379*** | -.0210** | -.0242** | .0265* | .0246 | -.0523*** | -.0588*** |
| | (-3.79) | (-4.18) | (-1.44) | (-2.48) | (-6.53) | (-6.06) | (-2.14) | (-2.32) | (1.70) | (1.66) | (-3.43) | (-3.70) |
| *lnFDI* | -.0035 | -.0024 | .0058 | .0154** | -.0048 | -.0027 | | | | | | |
| | (-1.08) | (-0.78) | (1.39) | (2.67) | (-1.01) | (-0.48) | | | | | | |
| *lnFAI* | .007986 | .0041 | .0112 | -.0121 | .0031 | .0016 | | | | | | |
| | (1.42) | (0.80) | (0.80) | (-0.86) | (0.41) | (0.21) | | | | | | |
| *lnIE* | -.0809 | -.0458 | -.0017 | .0010 | -.0011 | -.0008 | -.0984 | -.0465 | -.0065 | -.0056 | -.0006 | .0000 |
| | (-1.52) | (-0.79) | (-0.57) | (0.28) | (-0.49) | (-0.29) | (-1.12) | (-0.42) | (-0.91) | (-0.79) | (-0.16) | (0.02) |
| *$lnTE_0$* | .0079* | .0072 | .0156** | .0100 | | | | | | | | |
| | (1.84) | (1.67) | (2.01) | (1.19) | | | | | | | | |
| *Pop* | .0033 | .0032 | .0001 | .0006 | .0084 | .0086 | .0142*** | .0132** | .0004 | .0004 | .0293** | .0277** |
| | (1.03) | (0.99) | (0.03) | (0.12) | (1.34) | (1.32) | (2.77) | (2.51) | (0.05) | (0.06) | (2.66) | (2.41) |
| *South* | .0131*** | .0124*** | .0012 | -.0037 | .0234** | .0230** | .0143* | .0144* | -.0050 | -.0026 | .0335* | .0321* |
| | (3.14) | (2.85) | (0.13) | (-0.34) | (2.56) | (2.49) | (1.78) | (1.78) | (-0.36) | (-0.18) | (1.99) | (1.95) |
| *Middle* | .0162*** | .0154*** | .0067 | .0048 | .0287*** | .0272*** | .0166** | .0163** | .0115 | .0133 | .0272** | .0242** |
| | (4.98) | (4.77) | (1.25) | (0.79) | (3.79) | (3.59) | (2.57) | (2.51) | (1.04) | (1.18) | (2.24) | (2.06) |
| *constant* | .2172*** | .2322*** | .1993 | .3083** | .3105*** | .3370*** | .1845 | .2254* | -.3363* | -.3067 | .4225** | .5243** |
| | (3.97) | (4.28) | (1.99) | (2.64) | (4.35) | (3.84) | (1.57) | (1.80) | (-1.69) | (-1.63) | (2.15) | (2.46) |
| N | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| F test p-value | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| R-squared | 0.7706 | 0.7672 | 0.6693 | 0.6281 | 0.8459 | 0.8452 | 0.5352 | 0.5320 | 0.6177 | 0.6163 | 0.6779 | 0.6753 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels.
The dependent variable is the exponential growth rate of productivity over the 1996-2012 period in case of total GDP and over the 1999-2012 period for industry, because of missing data. The study of the standard deviation of the level of productivity reveals divergence up until 2004 for total GDP and 2005 for secondary industry, then convergence subsequently. To study the break, the sample is split in two periods. Output growth is the output (exponential) growth rate. All the other regressors are expressed in logarithmic terms.
$lnP_0$ is the log-level of productivity at the beginning of the period . lnFDI, lnFAI and lnIE are the averages over the periods of the logarithms of foreign direct investment, fixed assets investments (both expressed as percentages of GDP) and the public infrastructure expenditure (expressed as a percentage of the public spending). As the controls related to total GDP (FDI and FAI) they are dropped for industry. lnTE is the logarithm of output of the township enterprises expressed as a share of the output of total industry. Due to missing data, it is expressed as the average of the 1996 and 1997 observations. Pop is the number of persons employed in each city at the beginning of the period. South and Middle are geographical intercept dummies.
Preliminary specifications included also the logarithm of public education expenditure (as a percentage of the public spending). However, to construct a more reliable model, this regressor was dropped as it is strongly correlated with the level of productivity at the beginning of the period ( the degree of correlation is greater than 0.70 and the VIF greater than 5).
Figures in parentheses are the t-statistics. OLS and IV are ordinary least squares and instrumental variables (GMM) regressions. Where necessary, the regressions are controlled for heteroskedasticity. In case of IV regressions, the instruments are defined following the Durbin's ranking method, which involves ranking each value of a variable from 1 to *n* and then using the ranks as instruments.
Diagnostic tests (Moran's I, Lagrange Multiplier, Robust Lagrange Multiplier) reveal there is no spatial dependence in the data.

**Table 7. Dynamic Verdoorn Law Spatial Panel Autocorrelation Model§**

| | Dependent Variable: *Productivity growth, p* | |
|---|---|---|
| | GDP | Industry |
| *q* | .8693*** (11.93) | .8688*** (12.16) |
| *ρ* | .3075*** (3.20) | .4534*** (4.29) |
| *λ* | .3604*** (2.67) | .5390*** (9.64) |
| *Time Dummies* | yes | yes |
| N | 976 | 793 |
| Number of cities | 61 | 61 |
| Panel length | 16 | 13 |
| R-squared | | |
| Within | 0.3215 | 0.0990 |
| Between | 0.2090 | 0.3034 |
| Overall | 0.3170 | 0.1063 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels.
§Spatial panel auto-regressive model with spatially auto-regressive disturbances (two-way fixed effects).
$\rho$ is the spatial autocorrelation coefficient; $\lambda$ is the spatial error term coefficient.
The sample covers the periods 1996-2012 in case of total GDP and the 1999-2012 period in case of industry (because of missing data). The figures in brackets are the t-statistics. All the estimation results are controlled for heteroskedasticity.

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***The Static Verdoorn Law***

As we have seen, the Verdoorn law may be derived from a conventional Cobb-Douglas production function by differentiating the function with respect to time and rearranging the equation so output growth is specified as the exogenous variable. Consequently, we should also be able to estimate the law in log-level form using the same data set and obtain the identical parameter values. However, when this is done for the OECD countries or the US states a paradox arises. Using the same data set, when exponential growth rates are used, the estimates suggest substantial economies of scale, whereas using the log-level specification gives constant returns to scale (McCombie 1982). McCombie and Roberts (2007) have shown both theoretically and using simulation analysis that, at the regional level, this is likely to be due to spatial aggregation bias. This arises because the spatial unit of observations, such as the US states or UK regions, are determined by administrative, rather than economic, considerations.

Suppose, for example, that the correct spatial economic unit of observation (the functional economic area [FEA]) is determined by the extent of the journey-to-work. The number of FEAs in a region will vary depending upon the size of the region and this will bias the estimates towards constant returns to scale. It can be shown that using growth rates minimizes the degree of bias.

Table 8 presents the results for the estimation of the static Verdoorn law, i.e., the law in log-level form. It was estimated using a spatial panel auto-regressive model with spatially auto-regressive disturbances (two-way fixed effects). The estimates are controlled for spatial autocorrelation which is now found to be present. No paradox arises because the estimates demonstrate substantial economies of scale for both industry and GDP, with the estimated value of the Verdoorn law towards the upper limit of the estimates found using exponential growth rates. The fact that the paradox is not found is plausibly due to the fact that each city corresponds to a single FEA, which differs in magnitude with the city's population size or level of output. Consequently, both the static and dynamic estimates of the Verdoorn coefficient should be of a similar magnitude, as, in fact, turns out to be the case.

**Table 8. Static Verdoorn Law. Spatial Panel Autocorrelation Model§.**

| | Dependent Variable: The log of productivity ln *P* | |
|---|---|---|
| | GDP | Industry |
| *ln Q* | 0.7513***<br>(7.44) | 0.8361***<br>(10.15) |
| $\rho$ | 0.2061<br>(1.21) | -0.9799***<br>(-2.77) |
| $\lambda$ | 0.4046*<br>(1.76) | 2.584***<br>(21.90) |
| *Time Dummies* | yes | yes |
| N | 1037 | 854 |
| Number of cities | 61 | 61 |
| Panel length | 17 | 14 |
| R-squared | | |
| Within | 0.9649 | 0.8847 |
| Between | 0.6764 | 0.5789 |
| Overall | 0.8130 | 0.5742 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels.
§Spatial panel auto-regressive model with spatially auto-regressive disturbances (two-way fixed effects).
The dependent variable is the natural logarithm of the annual level of productivity (logarithm of GDP per person employed).
*Q* is the level of annual output. $\rho$ is the spatial autocorrelation coefficient; $\lambda$ is the spatial error term coefficient.
The sample covers the 1996-2012 period in case of total GDP and the 1999-2012 period in case of secondary industry because of missing data. The figures in brackets are the t-statistics. All the estimation results are controlled for heteroskedasticity.

## 6. Theil's Entropy Index and Panel Data Analysis

Given the prevalence of increasing returns to scale, we next investigate the degrees to which regional disparities in productivity growth have been changing in the province.

Since 1950s, four different statistical approaches have been utilised to quantify regional disparities, which include the coefficient of variation, Gini coefficient, Theil's entropy index and Atkinson index (Wei & Kim, 2002; Zhang, 2010). Theil's entropy index is useful in decomposing disparity into within- and between-region inequalities (Wei & Kim, 2002).

For the purpose of this study, a careful examination of the change in the degree of inequality is needed. Two Theil indices can be defined: Theil-L and Theil-T. The former emphasises the inequality of the people, while the latter shows the inequality in output across different regions, and Theil-T (commonly referred to as Theil index) is more frequently used (Lu & Xu, 2005; Cheong, 2012). Because we are measuring inequality between groups, and group's income and population shares are known, the Theil index can be calculated using the equation below (Conceicao & Ferreira, 2000):

$$T = \sum_{i=1}^{N} Y_i \ln \frac{Y_i}{P_i} \tag{25}$$

where N is the number of cities in Jiangsu Province, $Y_i$ the share of GDP of the ith city in Jiangsu, $P_i$ the proportion of population of the ith city in Jiangsu. A larger T indicates greater inequality among cities.

Furthermore, according to Novotný (2007), inequalities across a number of regions can be decomposed into two components, one being the disparity between subgroups' mean, and the other being the sum of disparities within certain subgroups. Zhang (2010) also finds that Theil's entropy index can be decomposed into $T_{WR}$, which measures the inner-region disparity within each of the three regions, and $T_{BR}$, which is the between-region inequality index. For the purpose of our analysis, we are interested in the between-region disparity, $T_{BR}$. The Theil's entropy index can be decomposed into:

$$T = T_{BR} + T_{WR} = \sum_{i=1}^{3} Y_i \ln \frac{Y_i}{P_i} + \sum_{i=1}^{3} Y_i \left[ \sum_j Y_{ij} \ln \frac{Y_{ij}}{P_{ij}} \right] \tag{26}$$

where $Y_{ij}$ is the share of the *j*th city's GDP in the *i*th regional, and $P_{ij}$ is the share of population.

Because there are potentially increasing returns to scale present in our previous analysis, it would be prudent to take an approach which does not impose any degree of returns to scale on the analytical framework. Regression analysis based on Theil index suits this purpose well. Furthermore, it enables us to explore causes of the output inequality across three regions in Jiangsu. By utilising a panel least squares model, we can test the impact of disparities in rural industrialisation, FDI, education expenditure and infrastructure on regional disparity. To do so, Theil indices of rural industrialisation (using number of rural industrial worker as a proxy), FDI, education expenditure, and infrastructure (using the length of high-grade motorways as a proxy) are also calculated. Due to data availability issues, the dataset is slightly different from the one used in previous models.

The specification of the panel data analysis is as follows, which is based on the framework developed by Gries and Redlin (2009):

$$T\_GDP_{i,t} = \alpha + \beta_1 T\_RI_{i,t} + \beta_2 T\_FDI_{i,t} + \beta_3 T\_Eduexp_{i,t} + \beta_4 T\_Infra_{i,t} + \beta_5 Dummy\_policy_{i,t} + \mu_i + \varepsilon_{i,t} \quad (27)$$

where $T\_GDP_{i,t}$ is the contribution of region i to the province's Theil index of GDP, or $Y_{i,t} \ln \frac{Y_{i,t}}{P_{i,t}}$; $T\_RI_{i,t}$ is the Theil index contribution of number of rural industrial worker $RI$, or $RI_{i,t} \ln \frac{RI_{i,t}}{P_{i,t}}$; $T\_FDI_{i,t}$ denotes the Theil index share of $FDI$, or $FDI_{i,t} \ln \frac{FDI_{i,t}}{P_{i,t}}$ ; $T\_Eduexp_{i,t}$ is the Theil index contribution of education expenditure, or $eduexp_{i,t} \ln \frac{eduexp_{i,t}}{P_{i,t}}$ ; $T\_Infra_{i,t}$ is the Theil index contribution of the length of high-grade motorway, or $infra_{i,t} \ln \frac{infra_{i,t}}{P_{i,t}}$.

$Dummy_policy_{i,t}$is a dummy variable capturing the effect of the core regional policies implemented between 2004 and 2005. It is 1 for post-2005 samples and 0 for pre-2005 samples.

If the coefficient is negative and statistically significant, there is evidence that these regional policies are effective in closing the development gap across three regions.

**Estimation Results**

Because the definition of three regions has changed, and some region-level data are not available from 1996 to 1999, the period included in the analysis is from 2000 to 2012. We then examine the change in the degree of inequality. Theil indices are calculated using GDP and population data from Jiangsu Statistical Yearbooks 2000-2012. The results are shown in Table 9 below.

**Table 9. Theil Indices 2000-2012**

| Year | T | $T_{BW}$ | $T_{WR}$ | Subei* | Sunan* | Suzhong* |
|---|---|---|---|---|---|---|
| 2000 | 0.2304 | 0.1594 | 0.0710 | 0.1193 | 0.0482 | 0.0799 |
| 2001 | 0.2375 | 0.1661 | 0.0714 | 0.1183 | 0.0487 | 0.0833 |
| 2002 | 0.2499 | 0.1746 | 0.0752 | 0.1166 | 0.0562 | 0.0846 |
| 2003 | 0.2862 | 0.2020 | 0.0841 | 0.1407 | 0.0645 | 0.0840 |
| 2004 | 0.2972 | 0.2072 | 0.0899 | 0.1621 | 0.0672 | 0.0848 |
| 2005 | 0.3046 | 0.2173 | 0.0873 | 0.1532 | 0.0686 | 0.0797 |
| 2006 | 0.3045 | 0.2158 | 0.0887 | 0.1466 | 0.0725 | 0.0817 |
| 2007 | 0.3007 | 0.2136 | 0.0871 | 0.1405 | 0.0743 | 0.0734 |
| 2008 | 0.2933 | 0.2060 | 0.0872 | 0.1248 | 0.0838 | 0.0579 |
| 2009 | 0.2731 | 0.1921 | 0.0809 | 0.0973 | 0.0827 | 0.0569 |
| 2010 | 0.2625 | 0.1842 | 0.0783 | 0.0940 | 0.0789 | 0.0582 |
| 2011 | 0.2529 | 0.1799 | 0.0729 | 0.0815 | 0.0757 | 0.0542 |
| 2012 | 0.2478 | 0.1800 | 0.0678 | 0.0742 | 0.0700 | 0.0529 |

*: These figures are the within region Theil Index

Figure 2 shows the changes in between-region Theil indices and within-region inequality. Details of within-region inequalities are shown in Figure 3. Several findings can be drawn from these tables and figures.

First, the disparity across Jiangsu cities has been rising from 2000 to 2004, and declining from 2005 onwards. The increase in inequality between 2000 and 2004 reflects the fact regional policies failed to close the development gap. The government has had a clearer picture of its role in regional development since 2004. This implementation of three core regional policies was accompanied by a decline in both between-region and within-region disparities after 2005.

Secondly, the between-region disparity has been clearly greater than the within-region disparity. This shows that on average 70% of the inter-city disparity is explained by the disparity between Southern, Central and Northern regions.

Finally, the lagging North has the highest disparity across cities, while the degree of the disparity has been declining since 2004. In comparison, the most prosperous region, Sunan, had the lowest disparity before 2007. The Theil index of Sunan has been rising since 2001. Suzhong outperformed other regions in terms of equality across cities, and there is a clear trend of declining disparity.

**Figure 3. Decomposition of the Theil Indices**

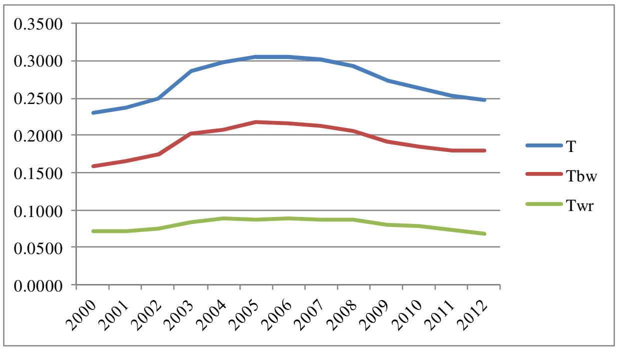
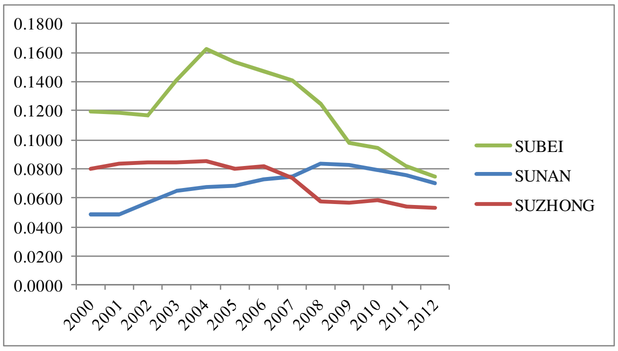



**Figure 4. Within-region Theil Indices**




The results of the panel data analysis are displayed Table 10.

To solve the omitted variable problems, we run fixed effects regressions (or unobserved effects models) to control for time-constant, unobserved, factors that affect $T\_GDP_{i,t}$.

**Table 10. Theil Index Panel Data Analysis, 2000-2012**

| | Dependent Variable: $T\_GDP_{i,t}$ | |
|---|---|---|
| | FE regressions | |
| $T\_RI_{i,t}$ | -.0084<br>(-0.27) | .0118<br>(0.64) |
| $T\_FDI_{i,t}$ | -.0824*<br>(-3.10) | -.1013**<br>(-6.70) |
| $T\_EduEx_{i,t}$ | .6011**<br>(6.39) | .5726**<br>(9.21) |
| $T\_InfExp_{i,t}$ | .3132***<br>(4.54) | .3382***<br>(26.52) |
| *Policy* | -.0007<br>(-0.28) | .0068<br>(0.94) |
| *Time dummies* | - | yes |
| *Constant* | .0610***<br>(18.03) | .0632***<br>(88.51) |
| N | 39 | 39 |
| Number of Regions | 3 | 3 |
| R-squared<br>Within<br>Between<br>Overall | <br>0.7991<br>0.9969<br>0.9746 | <br>0.8698<br>0.9932<br>0.9594 |

*Notes:*
Superscripts */**/*** denote 10, 5, and 1 percent significance levels.
Figures in brackets are the t-statistics. The regressions are controlled for heteroskedasticity. T_GDP is the contribution of region i to the province's Theil index of GDP. T_RI is the Theil index contribution of number of rural industrial workers. T_FDI denotes the Theil index share of FDI. T_EduEx is the Theil contribution of education expenditure. T_InfExp is the Theil index contribution of the length of high-grade motorway. Policy is a dummy variable capturing the effect of the core regional policies implemented between 2004 and 2005. It is 1 when year is greater than 2004.

Wei and Kim (2002) find that FDI is an important determinant of uneven growth across regions in Jiangsu. The result in this study challenges this finding. Controlling for other variables, the openness inequality measured by Theil contribution of FDI has a statistically significant but negative effect on inequality. The literal meaning of the negative sign is that the uneven levels of FDI contribute to a more equal dispersion of GDP. However, it is hard to reconcile this finding with results from the constant returns model, where higher FDI flows are associated with higher per capita output growth. A careful examination of the dataset reveals that between 2000 and 2012, FDI disparity exhibits a declining trend, relative to GDP inequality. Therefore, declining regional disparity in FDI is *accompanied* by a higher degree of regional GDP equality. It would be arbitrary to establish any causal relationship here. So far as Jiangsu Province is concerned, FDI is and will be playing an important role in accelerating economic growth (Shen,2007; Wei and Kim, 2002).

The result shows that controlling for other variables, the inequality contribution of rural industrialisation is not statistically significant and even negatively correlated with the contribution of income inequality. It implies that regional inequalities in the rural industrial development do not contribute to the income disparity. This clearly contradicts Rozelle's (1994) finding that the differing levels of rural industrial development can explain part of the inequality in Jiangsu. One interpretation could be that the importance of rural industrial sector has become less and less relevant in explaining regional disparity in the province in recent years, due to the rising urbanisation rates across all regions. Another reason might be that numbers of rural industrial workers are used as a proxy for the rural industrial development. Unlike fixed asset investment in TVEs which measures the capital investment, this variable measures the share or importance of the rural industrial sector, relative to the whole regional economy. On this basis, the finding is consistent with that in the constant returns model where the share of rural industrial output is not an important explanatory factor. Notice that it does not disprove the importance of *investments* in the rural industrial sector.

Government policies aimed to enhance human capital stock are expected to have a significant impact on the level of development (Zhou, et al., 2009). In line with the existing literature, the effect of the inequality contribution of education expenditure is statistically significant, and there exists a positive correlation. In addition, the coefficient of the inequality contribution of infrastructure is positively and significantly correlated with income inequality. The result reaffirms the importance of infrastructure provision in stimulating economic development, as is asserted by Demurger et al (2001), Guan, Zhao and Lin (2004), and Huang and Luo (2009).

Notice that the coefficient of the policy dummy is negative, holding all other variables constant. This implies that the implementation of the three core regional policies contributes to higher regional equality, compared with the pre-2005 period. However, the coefficient is not statistically significant, showing that the effect of regional policies is likely to be limited or even non-existent.

## 7. Conclusions

Thirty-five years after the implementation of the reform and opening-up policy, Jiangsu Province is now one of the most prosperous regions in China, benefiting from the vibrant private sector, huge flows of international trade and the Central Government's preferential policies. Yet, the striking inequality among three regions of Jiangsu is worth our attention.

Using data from 1996 to 2012, the result of the neoclassical approach shows that there is evidence of convergence across 61 cities, although the catch-up process is more evident within each region than across three regions. It is found that investments in TVEs are important for economic growth, while the effects of infrastructure expenditure are limited. On the other hand, the Verdoorn law approach reveals strong increasing returns to scale, and there is a significant technological diffusion process between 1996 and 2012. This has been shown also in a panel setting with a specification modelling all components of any possible spatial autocorrelation.

As the neoclassical approach assumes constant returns while the Verdoorn law captures the role of increasing returns, the two approaches are by definition mutually exclusive. In the augmented Solow model, it is assumed that different cities or regions have the same level of technology. Consequently, the incorporation of the output at the beginning of the period measures the growth in productivity attributable to the deviation of the capital/labour ratio from its steady-state value. In comparison, the augmented Verdoorn framework allows technological levels to differ across cities by introducing the initial output level. Therefore, in the Verdoorn law, the output at the beginning of the period is a measure of diffusion of innovation. Thus, the evidence that the diffusion of technology from advanced to backward regions has an effect on productivity growth is compatible with cumulative causations.

However, when we consider the estimating equation, it can be seen that the Solow growth model is nested within the Verdoorn law. If constant returns to scale exist, then the Verdoorn coefficient should be statistically insignificant. In this case, the specification is identical to the Solow growth model. The fact that it is statistically significant refutes the Solow growth model's assumption of constant returns to scale and the inevitable tendency towards convergence.

The analysis of the evolving pattern in disparity across cities shows that the between-region disparity explains more than 70% of inter-city disparities in Jiangsu. This is consistent with the findings in the convergence analysis that convergence is more evident within each region. As a way to mitigate the problems associated with returns to scale, panel data analysis based on Theil entropy index is performed. This approach does not explicitly or implicitly impose any degree of returns to scale on the model, and it helps to identify the causes of output disparity across the three regions. Inequalities in education and infrastructure provision have been associated with higher degrees of regional disparity, while the inequality in rural industrial development has no significant impact on the output disparity. The effect of the core regional policies implemented between 2004 and 2005 has a limited impact on alleviating disparity across the regions.

Taking a synthesised view, the government is advised to encourage TVE investments in the Northern cities, so that these lagging cities can catch up. Regional policies should focus on lowering the degree of inequality in education and infrastructure provisions across Sunan, Suzhong and Subei. Indeed, one of the key reasons for the lagging North is the lack of human capital stock (Zhou, et al., 2009). Policies that aim to relocate industrial sites from South to North might adversely impact on the human capital developments in Subei, as the relocated industries are often low-end, low-skill and labour-intensive (Zhou, et al., 2009). It is also widely recognised that the substandard infrastructure in Suzhong and Subei is impeding economic development. The quantitative analysis in the research provides further support for government efforts to improve the provision of infrastructure in Central and Northern Jiangsu. It should be noted, however, that the problem of the 'prosperity trap' has not been alleviated, as the Jiangsu government benefits hugely from tax revenues collected from Sunan, and therefore aims to preserve business competitiveness in this region (Zhou, et al., 2009).

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## Appendices

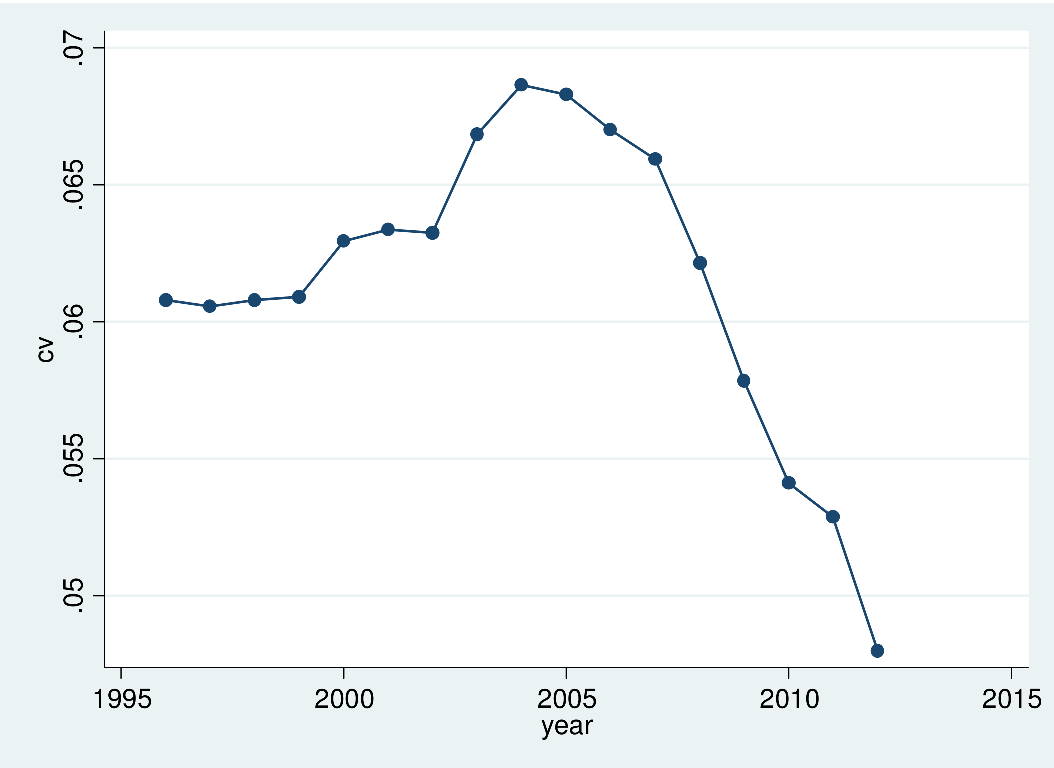
### 1. GDP per capita of each prefecture, 2012

| Prefecture | GDP per capita (registered) |
|---|---|
| Suzhou | 186,208 |
| Wuxi | 161,361 |
| Nanjing | 112,980 |
| Changzhou | 109,118 |
| Zhenjiang | 96,839 |
| Yangzhou | 63,871 |
| Nantong | 59,587 |
| Taizhou | 53,315 |
| Xuzhou | 40,835 |
| Yancheng | 37,977 |
| Huai'an | 35,245 |
| Lianyungang | 31,558 |
| Suqian | 27,293 |

### 2. Sigma Convergence

a) TOTAL GDP

Plot of the coefficient of variation for the logarithm of GDP per person employed



b) SECONDARY INDUSTRY

Plot of the coefficient of variation for the logarithm of GDP per person employed