Industrial Agglomeration and Wage Inequality in China

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Abstract: This paper estimates nonlinear structural wage equations derived from NEG models with data on 327 cities in China. The estimation results show that the variation of wage level across cities in China is associated with proximity to large markets. The estimated elasticity of substitution of China is smaller than those of the other countries studied in previous research. It indicates that with the same increase of sub-regional market size, China may suffer more serious regional inequality problems. My estimation shows that although increased agglomeration can increase each city's wage level, it may also increase the wage gap between large and small cities.

Key Words: New Economic Geography, Wage Inequality, Elasticity of Substitution

JEL Classification: F12, O24, R12

1. Introduction

Since the beginning of its open door policy in 1978, China's economy has grown spectacularly for 30 years. From then to 2005, China's Gross Domestic Product (GDP) rose, in constant 2000 US$, from US $157.7 billion to US $1,889.9 billion,[1] giving an average annual GDP growth rate of 9.6%. China's exports and imports have grown even faster during the same period, with average annual growth rates of 12.6% and 13.3% respectively. Along with China's rapid economic and trade expansion, multinational companies continue to move their labor-intensive production to China due to its abundant labor endowment. This further induces the huge flow of foreign direct investment (FDI) into China.

[1] *World Development Indicators*, World Bank (2007).

However, the locations of China's exporting industries and the destinations of FDI flowing into China have displayed significant spatial concentration in China. In 2006, over 31 percent of China's exports were from Guangdong province and more than 75% of FDI flowed into its coastal regions.[2] It seems that it is China's coastal regions that hold comparative advantage over many other countries as well as other regions of China, gain large world market share of labor-intensive products and absorb a huge amount of the world's production resources [Tuan and Ng (2004)]. Labor-intensive economic activity is agglomerating in China's coastal regions.

One of the most important reasons that caused this agglomeration is believed to be the Chinese government's reform strategy------ "let some people and some regions get rich first; the rich people and regions should then pull the rest of the country to get rich" [Deng, (1994)] and the corresponding economic policies[3]. Some preferential policies were implemented in China's coastal region which sped up the development of those regions and made them more competitive and wealthier than the rest of the country.[4]

Tuan and Ng's (2004) research indicates that the process of legal modernization and policy reforms via institutionalization, which has significantly lowered both domestic and international trade costs of China, has strong effects on China's development distribution. Their study is based on Krugman's (1991) well-known New Economic Geography (NEG) model----- the Core-Periphery (CP) model. The CP model shows that a larger economy, which has both a larger labor endowment and a larger local market,

[2] Values are calculated from data in NBSC (2007). Please see Van Huffel, Luo and Catin (2005) for more detailed review on the concentration of economic activities in China.
[3] The role of China's trade policies on firm location is discussed in Batisse and Poncet (2004) and Jin (2004).
[4] In general, preferential policies include preferential tax treatment and direct local authorization for approval of FDI utilization. Please see Tuan and Ng (2001) for more detail.

tends to be more attractive to manufactures due to the existence of economies of scale and trade costs. The concentration of manufactures in the larger economy increases the demand for labor and lifts its wage level. The higher wage level attracts more labor to the larger economy which further increases the larger economy's labor endowment and local market size. The process continues until all manufactures agglomerates to the larger economy. Tuan and Ng's conclusion supports the argument that institutional changes affected the distribution of economic activities in China. However, their study did not tell us whether the labor endowment and market size affected the distribution of economic activities as well as the regional wage levels in China as CP model predicted.

In reality, the large population, and thus large potential market size and labor supply, is the most important reason that China's development attracts extra attention and raises concerns. At the same time, the problem of sharp disparities in wages and income levels of households between coastal areas—where most business activities are located—and inland provinces has been serious.[5] This has induced the "floating" population of internal migrants seeking improved income, and the associated severe congestion and environmental problems. All these problems have threatened the continuance of China's economic development. In this paper, I study the interaction of China's regional labor endowment, market size and wage level from a NEG perspective.

Much NEG empirical work has been done to study the effect of agglomeration on wage levels and the regional income (market size). Two methods that are widely used are the market-potential method [Brakman, Garretsen and schramm (2003), Hanson (2005)] and the market-access method [Redding and Venables's (2004)]. Hanson derives a full

[5] The role of trade opening in altering economic disparities in China is assessed in Anderson et al. (2003).

structural equation of wage based on Helpman's (1998) NEG model and estimates the wage equation with US data on employment, income, and housing stocks as right-hand side variables. On the other hand, Redding and Venables (2004) estimate the cross-country correlation between per capita income and the proximity to demand and supply markets, where the latter is constructed from estimated parameters of a gravity model of trade. Due to the lack of data on sub-regional trade within China, I use Hanson's method in this paper.

2. Literature Review

There are also other empirical works on spatial distribution of economic activities within China. Based on provincial data from 1988 to 1997, Catin and Van Huffel (2003) test two hypotheses: 1) whether the openness has reinforced a polarization process that characterized the second stage of development, 2) whether the progressive specialization in high-tech industries leads to a diffusion of the labor intensive activities to the inland provinces. Their results show that high-tech industries are concentrated highly in the coastal provinces. At the same time, the concentration in labor-intensive industries decelerates or even decreases in the coastal region. But this movement is just from the more developed coastal provinces to the less developed coastal provinces and does not significantly modify the major trends of the location and specialization of industries in the inland region. This finding provides strong support for the importance of my study. First of all, it confirms that the concentration of economic activities does exist in the different development stages of China at both sub-regional and national levels. Secondly, their empirical tests focus on the effects of the gradual open-door policies and the inflow of FDI on the spatial distribution of the Chinese economy. They do not analyze the detailed market potential or market access. How well the NEG framework can work for the case of China still needs to be tested. Finally, the data they use is at the provincial level for the period 1988-97. However, the rural-urban disparity and the hierarchy of cities may make the welfare effect of the concentration more significant [Brakman et. al. (2005)]. At the same time, their study is based on an immobile labor assumption, but the extent of labor mobility in China has increased since 1990s.[6] This suggests that their conclusions may change substantially with a data update.

Au and Henderson (2002) estimate the relationship between city-level per capita output in the non-agricultural sector and several determinants: capital stock to labor ratio, share of accumulated FDI in capital stock, distance to the coast, education and scale measures (city employment, employment squared, and employment interacted with the manufacturing to service ratio). They divide the data into the 1990-92 "planning" period and the 1995-97 "market" period and regress separately. Their results confirm that worker productivity is shown to be an inverted U-shape function of the city employment level, with the peak point shifting out as industrial composition moves from the manufacturing sector to the service sector as predicted by urban theory. They also argue that the majority of Chinese cities are shown to be potentially undersized – below the lower bound on the 95% confidence interval of the size where their output per worker peaks – and so there could be large gains from increased agglomeration in both the rural industrial and urban sectors. The purpose of Au and Henderson’s study is close to my empirical study. I want to test the effect of agglomeration on wage levels at the city level. However, our methods are quite different since I will use the nonlinear structural model derived from the NEG

[6] Please see Huang and Zhan (2005) for detail.

models. Instead of just estimating the linear relationships between per capita output and its determinants, I can estimate the structural parameters such as elasticity of substitution, share of industrial production in national production, share of capital in the industrial production and the trading cost parameter.

According to the above literature, China continues to face regional disparity problems caused by the concentration of economic activities. The factors that affect the spatial distribution and regional wage disparity of the Chinese economy are economic openness, industrialization, agglomeration, other factors or the combination of these factors. The effect of agglomeration has not yet been checked. Therefore, I try to explain the regional wage disparity in China from the NEG perspective in this paper.

3. The Model

3.1. The Wage Equation:

Based on Helpman's (1998) economic geography model, Hanson (2005) set up a full structural approach to consider wages inequalities in the economic geography framework. Basically, Helpman's model is very close to Krugman (1991)'s CP model and the functional equilibrium relationships look very similar for the two models. However, there is still an essential difference, as mentioned by Hanson, which makes the Helpman model more favorable for empirical work: Helpman uses housing, a sector with non-tradable products and exogenously fixed endowment to replace the agricultural sector in Krugman's CP model. As industrialization continues, the share of expenditure on agricultural products decreases, which weakens the importance of the agricultural sector to the economy substantially, especial in the urban area. However, the effect of housing on the economy will be relatively more stable across time, thus reduce the disturbance caused by factors other than the agglomeration effect. Since my study is based on China's city-level data, I use Helpman's model rather than Krugman's basic CP model in the following estimations. This can also make my estimation more comparable with Hanson's.

I assume that all consumers have identical Cobb–Douglas preferences over two bundles of goods, tradable manufacturing goods and housing services. A representative consumer in region k solves the problem:

$$\text{Max } U_k = C_{Hk}^{1-\mu} C_{Mk}^{\mu} \tag{3.1}$$

$$\text{s.t. } P_{Hk} C_{Hk} + P_{Mk} C_{Mk} = Y_k, \tag{3.2}$$

where C_{Hk} , C_{Mk} are consumption of non-tradable housing services and traded manufactures in country k respectively. P_{Mx}, P_{Hk}, Y_k are the price of manufactures, the housing price and the total output in country k.

The production function of manufactures is defined as:

$$X_{Mk} = C_{Lk}^{b} K_k^{1-b} = \left[\left(\sum_{i=1}^{n} c_{ik}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right]^{b} K_k^{1-b}, \tag{3.3}$$

where $C_{Lk} = \left(\sum_{i=1}^{n} c_{ik}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$ is the CES (Constant Elasticity of Substitution) aggregation of intermediate manufactures used in region k, K_k is the capital used by region k, n is the number of varieties of intermediate manufactures consumed by region k and $\sigma > 1$ is the elasticity of substitution[7] among varieties. To reflect the effects of both comparative

[7] I follow Ethier's (1982) assumption that the work of aggregating varieties can also be considered as a variety, so there is no extra labor needed in the aggregation production.

advantage and diminishing marginal returns, two variable inputs, labor and capital, are involved in the production of manufactures.[8] It is different from Helpman's model which only includes labor in manufacture production.

The production of an intermediate variety involves a fixed cost and a constant marginal cost: to produce x_i of good *i*, we need $L_i = \alpha + \beta x_i$ ($\alpha > 0$, $\beta > 0$), where L_i is the amount of labor employed to produce good *i*. Therefore, there are increasing returns in production of each intermediate manufacturing variety. In equilibrium, each variety is produced by a single monopolistically competitive firm and the f.o.b price of variety *i* produced in region *j* is $p_{ij} = \left(\frac{\sigma}{\sigma - 1}\right)\beta w_j$, where w_j is the nominal wage in region *j*.

There are *J* regions, *K* capital and *L* laborers in total, where laborers and capital are mobile across regions. With iceberg transportation costs in shipping goods between regions, the c.i.f price of good *i* produced by region *j* and sold in region *k* is

$$p_{ijk} = p_{ij} e^{\tau d_{jk}} \tag{3.4}$$

where τ is the unit transportation cost and d_{jk} is the distance between region *j* and *k*. Given the symmetry of intermediate manufactures in production and the mobile capital, the total sales of manufacturing goods by region *j* are[9]

$$\sum_k \sum_i p_{ijk} c_{ijk} = n_j r^{\frac{(b-1)(\sigma-1)}{b}} \sum_k \mu b Y_k \left[\frac{\sigma}{\sigma - 1} \beta w_j e^{\tau d_{jk}}\right]^{1-\sigma} P_{Mk}^{\frac{\sigma-1}{b}} \text{ }^{10} \tag{3.5}$$

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[8] For more details, please see Li (2008).

[9] Since the capital return is the same between regions but we have "iceberg" trade costs for any trade of manufactures, the trade of final manufactures will actually not happen. Please see Li (2008) for details.

[10] $c_{ijk} = C_{Lk} \left(\frac{P_{Lk}}{p_{ijk}}\right)^{\sigma}$.

where c_{ijk} is the amount of variety *i* that region *k* purchases from region *j*, *r* is the nominal return to capital. Monopolistically competitive firms earn zero profits. Therefore, the manufacturing sales in region *j* equal wages paid to labor in *j*, which is $w_j n_j a\sigma$. We then can get the following function for wage:

$$w_j = \theta r^{\frac{(b-1)(\sigma-1)}{b\sigma}} \left[\sum_k Y_k e^{-\tau(\sigma-1)d_{jk}} P_{Mk}^{\frac{\sigma-1}{b}} \right]^{1/\sigma}, \quad \theta = \left(\frac{\mu b}{\alpha\sigma} \right)^{1/\sigma} \left(\frac{\sigma\beta}{\sigma-1} \right)^{1-\sigma} \tag{3.6}$$

where θ is a function of fixed parameters. This equation indicates that wages in a region are increasing in the income of surrounding locations, decreasing in capital return, decreasing in transportation costs to these locations, and increasing in the price of competing traded goods in these locations. The summation term measures the market potential of the region.

Since labor can move freely across regions, real wages are equalized. Thus we have

$$\frac{w_j}{P_{Hj}^{1-\mu} P_{Mj}^{\mu}} = \frac{w_k}{P_{Hk}^{1-\mu} P_{Mk}^{\mu}} = \delta, \quad \forall j \neq k \tag{3.7}$$

where δ is the equalized real wage.

In equilibrium, we also have housing payments equal housing expenditure,

$$P_{Hk} C_{Hk} = (1-\mu) Y_k . \tag{3.8}$$

From equation (3.6)-(3.8), I can derive a wage equation similar to Hanson's wage equation:[11]

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[11] Hanson's (2005) wage equation is

$$\ln(w_j) = \phi + \frac{(b-1)(\sigma-1)}{b\sigma}\ln r + \frac{1-\sigma}{b\mu\sigma}\ln\delta + \sigma^{-1}\ln\left(\sum_k Y_k^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hk}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_k^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right) \tag{3.9}$$

where $\phi = \ln\theta + \frac{(\mu-1)(\sigma-1)}{b\mu}\ln(1-\mu)$.

It can be rewritten in reduced form:

$$\ln(w_j) = \phi + B5\ln r + B6\ln\delta + \sigma^{-1}\ln\left(\sum_k Y_k^{B1} C_{Hk}^{B2} w_k^{B3} e^{B4d_{ik}}\right) \tag{3.10}$$

Parameters $B1$-$B6$ are reduced form coefficients to measure the effects of nearby region income, housing stock, wages, distance, capital return and real wage levels.

From equation (3.9), we can see that an increase in the return to capital will decrease the nominal wage. At the same time, higher income in nearby regions raises demand for traded goods produced in j (as long as $(\sigma-1)(\mu-1)+b\mu>0$ is satisfied)[12], and higher wages in nearby regions raise the relative price of traded goods produced in these regions, which also increases the demand for goods produced in *j*. The higher demand further increases the production in region *j* and raises the region's demand for labor and its nominal wages. In addition, larger housing stocks in nearby regions imply lower housing prices and higher employment in these regions and so higher nominal wage needed for region j to attract more labor. Finally, the summation expression measures the market potential of region *j*. The greater market potential a region has, the higher its wage level is.

$\ln(w_j) = \phi + \sigma^{-1}\ln\left(\sum_k Y_k^{\frac{\sigma\mu-\sigma+1}{\mu}} C_{Hk}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_k^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)$, where ϕ is also a constant.

[12] All my estimations satisfy this inequation.

4. Data and Estimations

4.1. Data Sources

I take cities in China as the geographic unit of analysis. The data required are wages, population, regional income, housing stocks and distance between cities. Data on distance between cities are driving distances in thousand kilometers downloaded from www.hua2.com (China Map Online). I measure a city's wage level by its average annual wage (in RMB yuan). The regional income is measured by each city's GDP in hundred million RMB yuan. Total personal housing area in square meter is used as proxy of housing stock. City-level data on average annual wage, population, GDP and per capita housing area are available in the China City Statistical Yearbook from 1990 to 2001 (They have stopped reporting the per capita housing area since 2002). Table 1 gives summary statistics on the variables. There are 327 cities. But data for some cities are missing in some years.

Table 1. Statistical Summary of Variables

Variables	GDP	GDP	GDP	Population	Population	Population
Year	2000	1995	1990	2000	1995	1990
Obs.	262.00	262.00	209.00	262.00	261.00	210.00
Mean	190.24	101.20	35.63	124.13	104.76	104.05
Standard Deviation	409.28	212.27	72.29	244.79	168.01	167.67
Skewness	6.48	7.05	6.77	8.62	6.55	5.94
Variables	housing	housing	housing	Wage	Wage	Wage
Year	2000	1995	1990	2000	1995	1990
Obs.	260.00	219.00	203.00	262.00	262.00	209.00
Mean	1,706.23	861.12	681.91	8,986.40	5,325.81	2,259.39
Standard Deviation	2,690.98	1,255.49	990.86	2,729.91	1,520.76	433.35
Skewness	7.10	6.13	6.10	1.60	1.41	1.57

Source: Author's calculations based on data in *China City Statistical Yearbook* (1990-2000)

Table 1 shows that the Pearson Index for GDP, Population and Housing Stock are far greater than 1, i.e., the distributions of these variables are positively skewed. Therefore, for the majority of the cities, the values of these variables are below average.

It means that the population and economic activities are concentrated in a small number of the cities.

To further check the concentration and agglomeration of economic activities in China, I calculate the Concentration and Agglomeration Theil indices (Theil, 1967) with city level data of 30 Provincial Capitals and Separate Planning Cities in 2004. The Concentration index is defined as follows [Brakman, et al. (2005)]:

$$T^f = \sum_{r=1}^{R} T_r^f = \sum_{r=1}^{R} \frac{x_r^f}{x^f}\left(\log\frac{x_r^f}{x^f} - \log\frac{n_r}{n}\right) \qquad (3.11)$$

where *f* is an industry index,

r is a region index,

R is the total number of regions,

x_r^f is the economic activity of industry *f* in region *r*,

x^f is total economic activity of industry f, $\sum_r x_r^f$,

n_r is the number of basic units of region *r* and

n is the total number of basic units, $\sum_r n_r$.

T^f compares each region *r*'s relative economic activity of industry f (x_r^f / x^f) with what it should have been on the basis of the relative number of basic units (n_r / n). The basic units can be land area, population, economic activity, sub-regions, etc. If the industry is proportionally represented, $x_r^f / x^f = n_r / n$, T^f will be 0; if the industry is over represented, $x_r^f / x^f > n_r / n$, T_r^f will be a positive number; if the industry is under represented, $x_r^f / x^f < n_r / n$, T_r^f will be a negative number. The logarithmic transformation and the weights guarantee that T^f increases in the inequality of the distribution of x^f with respect to *n*.

The agglomeration Theil index is:

$$T = \sum_{r=1}^{R} \frac{x_r}{x} \left(\log \frac{x_r}{x} - \log \frac{n_r}{n} \right) \tag{3.12}$$

where, x_r is total economic activity of region r , x is the total economic activity of the whole nation $\sum_{r=1}^{R} x_r$, n_r is the number of basic units of region *r* and *n* is the total

Table 2. Agglomeration and Concentration Indices in 2004 China
(Based on city-level data of Provincial Capitals and Separate Planning Cities)

Region	City	Economic Agglomeration based on regional GDP	Industrial Concentration	Agglomeration of Employment
North	Beijing	3.79	5.48	13.54
	Tianjin	1.66	6.57	1.24
	Shijiazhuang	-1.06	-1.37	-1.27
	Taiyuan	-0.27	-0.32	0.97
	Hohhot	0.00	-0.33	-0.03
Northeast	Shenyang	0.55	-0.68	-0.24
	Changchun	-0.35	-0.51	-0.55
	Harbin	-1.07	-1.70	0.56
East	Shanghai	12.64	26.75	2.52
	Nanjing	1.23	3.88	-0.03
	Hangzhou	2.46	5.77	-0.60
	Hefei	-0.69	-0.72	-0.69
	Fuzhou	0.21	-0.07	-0.37
	Nanchang	-0.55	-0.81	-0.48
	Jinan	0.47	0.16	-0.27
Middle	Zhengzhou	-0.41	-0.89	-0.42
	Wuhan	0.18	-0.79	0.69
	Changsha	-0.56	-1.07	-0.74
	Guangzhou	7.09	7.63	3.22
	Nanning	-1.14	-0.87	-1.01
	Haikou	-0.15	-0.23	0.10
Southwest	Chongqing	-5.54	-5.18	-5.45
	Chengdu	-0.62	-1.86	-0.98
	Guiyang	-0.56	-0.60	0.20
	Kunming	-0.45	-0.81	-0.15
West	Xi'an	-1.00	-1.28	0.22
	Lanzhou	-0.38	-0.32	0.30
	Xining	-0.36	-0.36	-0.28
	Yinchuan	-0.21	-0.23	0.32
	Urumqi	0.09	-0.16	0.78
	Agglomeration/ Concentration Index	14.99	35.11	11.10

Source: Author's calculations based on data in China Statistical Yearbook (2005) number of basic units, $\sum_r n_r$. Here, the basic unit can only be regions, population or area.

There are three kinds of indices shown in Table 2. The Economic Agglomeration indices use Regional GDP to measure the economic activities. The Industrial Concentration indices use regional industrial output to measure the industrial activities. The Employment Agglomeration indices use regional employment to measure the regional economic activities. All three indices use population as the basic unit. The city level data of the provincial capitals and the separate planning cities are used in calculation.

From the table we can see that the spatial concentration of economic activities is very significant in China. All three indices are greater than 10 at the national level. In general, more economic production (GDP) is located in Shanghai, Guangzhou and Beijing compared with other cities. Industrial activities are mostly concentrated in Shanghai, while employment is agglomerated mostly in Beijing.

Table 1 also shows that the distribution of average annual wage level is positively skewed, although it is not as significant as the distribution of the other three variables. According to the NEG model, a few cities, which have concentrated population and labor supply, will have higher than national average wages. The rest, majority of the cities will have lower than national average wages. Therefore, the skewness of wage level's distribution is consistent with NEG model's prediction.

4.2. Estimation Issues

The first issue is the measurement error problem. The desired city wage measure is for a worker with some constant level of skill. According to the NEG theory, the variation in the constant skill wage across locations reflects the regional variation in nominal wages caused by the spatial variation in industry location. However, the available wage measure is the average annual wage per worker of each city. The variation in city average wages may be due either to the variation in the constant skill wage or to variation in worker characteristics. At the same time, the city with favorable characteristics, such as convenient transportation, the presence of universities or preferential policies, may attract both industrial firms and more-skilled labor, therefore any correlation between wages and the market-potential may be a byproduct of a correlation between the city's labor skill level and the market-potential. For instance, a city with more universities may have relatively large supplies of skilled workers (because college graduates tend to look for jobs near their place of education) and relatively large concentrations of production (because students and faculty are a captive local market).To reduce the effect of measurement error mentioned above, Hanson (2005) takes time differences of the estimating equations. I follow his method and get the following specification for Eq. (3.9),

$$\begin{aligned}\Delta \ln(w_i) &= \frac{(b-1)(\sigma-1)}{b\sigma}(\ln r_t - \ln r_{t-1}) + \frac{1-\sigma}{b\mu\sigma}(\ln \delta_t - \ln \delta_{t-1}) \\ &+ \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hkt}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_{kt}^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right. \\ &\left. - \ln\left(\sum_k Y_{kt-1}^{\frac{(\sigma-1)(\mu-1)+b\mu}{b\mu}} C_{Hkt-1}^{\frac{(\sigma-1)(1-\mu)}{b\mu}} w_{kt-1}^{\frac{\sigma-1}{b\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\right] + \Delta v_{it}\end{aligned} \tag{3.13}$$

It can be written in reduced form:

$$\begin{aligned}\Delta \ln(w_i) &= B5(\ln r_t - \ln r_{t-1}) + B6(\ln \delta_t - \ln \delta_{t-1}) \\ &+ \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{B1} C_{Hkt}^{B2} w_{kt}^{B3} e^{B4 d_{ik}}\right) - \ln\left(\sum_k Y_{kt-1}^{B1} C_{Hkt-1}^{B2} w_{kt-1}^{B4} e^{B4 d_{ik}}\right)\right] + \Delta v_{it}\end{aligned} \tag{3.14}$$

The time difference removes the effect of city characteristics that vary little over time, such as the availability of agricultural land, convenient transportation, the presence of universities or preferential policies. Equation (3.13) should still be able to reflect the effects of economic activities, such as the factor movement, international trade and production relocation.

In Hanson's paper, the real wage is implicitly treated as constant and canceled out when taking the time difference. He gets the following wage equation:

$$\begin{aligned}\Delta \ln(w_i) = \sigma^{-1}\Bigg[& \ln\left(\sum_k Y_{kt}^{\frac{(\sigma-1)(\mu-1)+\mu}{\mu}} C_{Hkt}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_{kt}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right) \\ & - \ln\left(\sum_k Y_{kt-1}^{\frac{(\sigma-1)(\mu-1)+\mu}{\mu}} C_{Hkt-1}^{\frac{(\sigma-1)(1-\mu)}{\mu}} w_{kt-1}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{ik}}\right)\Bigg] + \Delta v_{it}\end{aligned} \qquad (3.15)$$

The corresponding reduced form is:

$$\Delta \ln(w_i) = \sigma^{-1}\left[\ln\left(\sum_k Y_{kt}^{B1} C_{Hkt}^{B2} w_{kt}^{B3} e^{B4 d_{ik}}\right) - \ln\left(\sum_k Y_{kt-1}^{B1} C_{Hkt-1}^{B2} w_{kt-1}^{B3} e^{B4 d_{ik}}\right)\right] + \Delta v_{it} \qquad (3.16)$$

Due to the complete labor mobility assumption, real wage (δ) is equalized across regions. However, it is not necessarily constant across time. From equation (3.7), we can have

$$\ln \delta_t - \ln \delta_{t-1} = (\ln w_t - \ln w_{t-1}) - \left(\ln\left(P_{Ht}^{1-\mu} P_{Mt}^{\mu}\right) - \ln\left(P_{Ht-1}^{1-\mu} P_{Mt-1}^{\mu}\right)\right) \qquad (3.17)$$

From equation (3.17) we can see that the time difference of $\ln \delta$ is the difference between the nominal wage inflation and the price index inflation. These two inflations can be different for the same year and the term $\ln \delta_t - \ln \delta_{t-1}$ can have non-zero value. Therefore, the term with real wage should be kept in the time difference equation. Since δ is constant across cities, $\ln \delta_t - \ln \delta_{t-1}$ is also constant across cities. Therefore, I use national real wage level to calculate the time difference of real wage. Similarly, I use the national nominal lending interest rate to calculate the time difference of $\ln r$ [13].

The remaining error term, Δv_{it}, is the change in the deviation of city average wages from city constant-skill wages. Hanson mentioned that this error term may be correlated with the change in the summation expression in equation (3.9), if regions that experience growth in demand for locally produced traded goods tend to attract workers with above average skills. To account for the possible correlation between the error term and the change in the summation expression, Hanson uses a GMM estimator with historical data on regional population growth lagged by 10 years or more as the instrument for the change in the summation. Due to the limit of data availability, I use nonlinear least square estimator in Stata 9.1 with the city population growth data lagged only 5 years as the instrument.[14]

The second estimation issue is that other factors that influence spatial agglomeration, such as supplies of FDI (Tuan and Ng, 2003, 2004), or the available exogenous amenities (Roback, 1982) or localized human-capital externalities (Rauch, 1993), may also influence the spatial distribution of nominal wages. I deal with this issue by including three control variables in the estimation: annual utilized FDI, changes in the share of the tertiary industry in a city's GDP and higher educated population.[15] Due to the data limitation, I cannot use measures of exogenous amenities mentioned by Roback

[13] The data for real wage and nominal lending interest rate are available in *China Statistical Yearbook* (1990-2001).
[14] Stata does not have nonlinear GMM estimator. But it provides a more general nonlinear estimator, nl, which can fit an arbitrary nonlinear function to the dependent variable by least squares.
[15] According to *China Statistical Yearbook*, economic activities are categorized into the following three strata of industry: Primary industry refers to agriculture, forestry, animal husbandry and fishery and services in support of these industries. Secondary industry refers to mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction. Tertiary industry refers to all other economic activities not included in the primary or secondary industries.

(1982), such as heating-degree days, cooling-degree days, average possible sunshine, etc. The amenities can be very important advantages for the development of the service industry in a city. Therefore, I use the changes in the share of the service industry in a city's GDP as proxy for the exogenous amenities. By regressing city average wage growth on city education, the specification captures the impact of both individual education and average city education on wages, which implicitly controls for human-capital externalities across workers within a city (Rauch, 1993). The city level data for utilized FDI, share of third industry in GDP and the higher educated population are also available in the China City Statistical Yearbook.

Other factors, such as technological spillovers, may also contribute to spatial agglomeration. Using external economies to explain spatial agglomeration has a long history in urban economics (Fujita and Thisse, 1996). However, spillovers tend to be assumed rather than derived in these models. As Hanson (2005) has mentioned, although spillovers between firms could certainly contribute to spatial agglomeration, the absence of microfoundations for this explanation perhaps makes it less compelling. Part of the appeal of the NEG models is that the pecuniary externalities arise endogenously through the incorporated scale economies at the firm level.

As China is an economy in transition, the structures of its production and consumption are both changing. This implies that the parameters in my structural wage equations, such as the elasticity of substitution, the share of housing expenditure in annual living expenses and the share of labor cost in industrial production, may not be the same for different years. Therefore, I estimate the equation for each individual year and check if there is any trend for the change of these parameters.

4.3. Estimation Results

Hanson estimated the reduced-form regression coefficient of the wage equation first. Then he derived the implied structural parameter. When I performed the nonlinear regression following Hanson's strategy, the R^2 values are smaller than 0.3 in most years, which are similar to Hanson's results.[16] But if I estimate the structural parameter directly, the R^2 increases to more than 0.5 in most cases, which means a great improvement in the fit of the regression. Table 3 and Table 4 report the direct nonlinear least squares estimation results for wage equations (3.15) and (3.13) respectively. The dependent variable is the log change in average annual wage. I report both the structural parameter estimates and the values of the reduced-form regression coefficient implied by these estimates. Consider first the fit of the regression. In Table 4, all structural parameters for my wage equation are precisely estimated with values within the theoretical range. However, Table 3 shows that for some years, Hanson's equation does not converge to the significant estimates with theoretically correct values. For the years 1993, 1996 and 1999, Hanson's method does not produce significant estimates for μ, the share of industrial consumption in total consumption, between 0 and 1. For the years 1991 and 1995, I find insignificant estimates for τ(>0), the unit transportation cost. As a result, the implied estimates for some of the reduced-form regression coefficients in equation (3.15) are not significant in these years. For the years 1990 and 1992, although the structural parameter estimates are significant within the theoretical value region, the implied reduced-form regression coefficients for regional personal income have the wrong sign. The reduced-form effects of personal income, wages and housing on market potential implied by my

[16] Please see APPENDIX for Hanson (2005)'s results.

wage equation, however, are broadly consistent with the Krugman model in all 11 years. Higher personal income, higher wages and higher housing stocks in surrounding locations are all associated with higher wages in a given city. Comparing values of the Akaike's information criterion (AIC), Schwarz criterion (BIC) and R^2 in Table 3 and Table 4, we see that my wage equation improves the fit of the regression in 6 of the 11 years. Therefore, in the following analysis, I focus only on results in Table 4. In unreported results, I performed the estimation with data excluding Provincial Capitals and Separate Planning Cities. The results are very similar to those for the full sample. Table 5 and Table 6 report results including controls for used FDI, human capital and exogenous amenities for the year 1991 and 1995-2001 (Time difference data for 1992 - 1994 are not available). These results are qualitatively similar to those without controls.

Consider next the value of the structural parameter estimates in Table 4. Consistent with theory, estimates of σ, the elasticity of substitution, are greater than 1. It ranges in value between 1 and 3 in most cases. This is roughly in line with Hanson's estimates based on Helpman's model (range between 2 and 4) but far below his estimates based on Krugman's model (range between 4 and 8). As Hanson has mentioned, recent estimates of σ in the empirical literature are concentrated between 4.0 and 9.0 (e.g., Feenstra 1994, Head and Ries, 2001), which is a range above the estimates in Table 4. The lower is the value of σ, the lower in absolute value is the own-price elasticity of demand for any individual good and the less competitive is the market for that good. Therefore, my estimation results indicate that the Chinese market is less competitive than the markets in the countries studied in previous research (such as the U.S. market). At the same time, the change of the estimated σ is not monotonic. This can be explained with two opposite effects of the trade across sub-regions. First, the trade diversifies varieties available in each region. As the number of varieties increases, the elasticity of substitution among varieties increase and the market is more competitive. On the other hand, as trade continues, each region will specialize in the industries that they have comparative advantage. For example, in the early years, almost every Chinese city had cloth producers. After years of trade and specialization, the cloth production concentrated in only a few cities now. The concentration of production decreases the market competition and the elasticity of substitution. I also find that the estimated σ for the years after 1997 are smaller than those for the years before 1997. It indicates that the specialization in specific industry may have made the sub-regions of China lose their diversification in intermediate inputs in the period of 1998-2001.

The estimates of μ, the expenditure share on traded goods, are between 0 and 1. This is also consistent with theory. With the ongoing urban housing reform and the associated increasing housing price and expenditure for Chinese household, the estimated values for μ of 0.82–0.99 may seem too high. This may be due to the restricted categorization of goods as either traded consumables or housing services as Hanson suggested. On the other hand, before the launch of China's urban housing reform, housing expenditure comprised less than 1 percent of a Chinese urban resident's annual salary or living expenses (Chen, 1996). After more than two decades' privatization and marketization, China's housing market today is still far from mature (Li and Yi, 2007). The 2000 Population Census of China shows that 41% of the owned homes were so called "fanggai fang", referring to homes bought from "work units" (most are state-owned enterprises or institutions) or the municipal housing bureau at subsidized prices.

Nine percent were "jingji shiyong fang", which is a special kind of commodity housing that developers are asked to build for low- and middle-income households. Only 13% of the owned homes were bought in the open market by individual households. The remaining 37% were self-built housing found mostly in middle-sized and small cities. Therefore, the low share of housing expenditure in Chinese household's living expense is reasonable to some extent. We can also see that the estimated values of μ after 1997 are lower than those before 1997. [17] This decreasing trend reflects the Chinese government's effort at further reforming the housing market.[18]

Estimated values of *b*, the share of labor cost in manufacturing production are between 0.7 and 1, which is consistent with the fact that the Chinese economy is labor intensive. There is also a rough decreasing trend for estimated values of *b*, especially when comparing the values after the year 1997 with those before 1997. China is transitioning towards a more capital intensive economy. If there are more data available for years after 2000, we may be able to see this decreasing trend clearer. Finally, the estimated values of τ, the unit transport costs, are much lower than those in Hanson's estimations. It may be caused by the Chinese government's heavy subsidy on gas consumption before 2000.

Table 4 also shows that the implied reduced-form coefficient estimates for market potential and neighbor cities' regional income increased during the studied period while those for distance, neighbor cities' wage level and housing stock, the national capital

[17] The estimation based on 1997's data appears abnormal when comparing with estimations for other years. The estimated values for structural function parameters are much higher than those for other years. The R^2 value is very low (lower than 0.05). The reason can be the low quality of data or the effect of a shock such as 1997 crisis, or something else. It needs further study in future. Therefore, I do not count the estimation results for 1997 when doing trend analysis in this paper.

[18] In 1997, Chinese government launched a series of new policies for further urban housing reform. For more details, please see Li and Yi (2007).

return and wage level decreased during the same period. It indicates that the effect of market potential and neighbor cities' regional income on a city's wage level is increasing, which is consistent with the Krugman model's prediction. If there are no other factors to impede this effect, it will continue until all economic activities agglomerate into one big city. Capital return and real wage level have negative effects on a city's wage level. But their effects are decreasing in China as shown in Table 4.

In unreported results, I estimate equation (3.13) with data on regional population growth lagged by 3-5 years as the instrument for the change in the summation. The including of instruments does not improve the estimates of structural parameters much. But the values of R2 decrease dramatically to around 0.1. It may be caused by the low quality instruments since I do not have data of city population growth lagged by a longer period (10 or more years) as Hanson used.

5. Conclusions and Discussion

In this paper, I use data on 327 cities in China to estimate nonlinear wage equations derived from NEG models. These models attribute the geographic concentration of economic activities to product-market linkages between regions that result from scale economies and transport costs. My estimation results are broadly consistent with this hypothesis. Regional variation in wages is associated with proximity to large markets.

One contribution of the paper is estimation of a structural wage equation and the parameters such as the elasticity of substitution, the share of housing expenditure in a Chinese urban resident' s annual living expenses and the share of labor cost in industrial production in China. Estimates of the model's parameters are broadly consistent with theory. The estimated elasticity of substitution of China is smaller than those of the other countries studied in previous research. It indicates that the effect of market potential, and therefore the agglomeration effect, is greater in China than in other countries. Thus, with the same increase of sub-regional market size, China may suffer more serious regional inequality problems. The estimation results also show that the estimated values of elasticity of substitution for the years after 1997 are smaller than those for the years before 1997. The reason could be that most small and middle-sized cities specialize in just a few industries with specific technology. Each city obtains strong market power in their specialized industries. But at the same time, each city loses its diversity of production. As a result, the elasticity of substitution on intermediate products decreases in these small and middle sized cities, which indicates a stronger market potential effect. This further accelerates the increase of wage difference between cities and the agglomeration of each industry into the city with the strongest technology and market power in that industry. Therefore, increasing small cities' economic sizes and diversifying their industry composition may help decrease the wage inequality between cities in China. Au and Henderson (2002) also argue that the majority of Chinese cities should increase their economic size to reach the output per worker peaks. They further state that there could be large gains from increased agglomeration in both the rural industrial and urban sectors. However, my estimation shows that although increased agglomeration can increase each city's wage level, it may also increase the wage gap between large and small cities.

Similar to Hanson's study, my estimations, of course, do not rule out the possibility that other factors also contribute to spatial agglomeration. My estimation results are not qualitatively affected by introducing controls for FDI, human capital externalities or exogenous amenities or by instrumenting for the market-potential term. But there are still other factors, such as the technology spillovers between firms, for which I do not control and which could have important effects on industry location.

My estimation results also show that the share of housing expenditure in a Chinese urban resident's annual living expenses is still very low, although the housing prices in some major Chinese cities such as Beijing and Shanghai now exceed those in many US cities. This share will increase in the near future, as China's urban housing reform is going on and the share of the population who obtain homes at lower than market price from the old housing institution is decreasing. The estimated share of capital cost in industrial production is also very low, which is consistent with the fact that the Chinese economy is labor intensive. But the roughly increasing trend shows that China is transitioning towards a more capital intensive economy.

There are still some of the concerns about the empirical results. They can conceivably be remedied through improving data quality or generalizing the NEG model, such as by introducing more heterogeneity in industry production and trade costs or by allowing for other motivations for spatial agglomeration.

Table 3. Nonlinear Least Square Estimation Results for Hanson's Wage Equation without Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	4.54	3.20	2.96	2.17	5.48	2.15	2.21	1.46	1.14	2.81	4.24
	(0.116)	(0.288)	(0.149)	(0.072)	(0.200)	(0.056)	(0.348)	(0.079)	(0.124)	(0.272)	(0.382)
τ	0.45	0.00	0.90	0.17	0.16	0.00	0.08	3.22	4.91	0.05	0.18
	(0.021)	(0.034)	(0.083)	(0.052)	(0.014)	(0.053)	(0.138)	(0.580)	(3.778)	(0.042)	(0.029)
μ	0.70	0.70	0.57	1.00	0.93	0.96	1.00	0.52	0.35	1.00	0.93
	(0.006)	(0.043)	(0.017)	(0.027)	(0.007)	(0.021)	(0.015)	(0.041)	(0.183)	(0.010)	(0.005)
Implied values											
Market potential	0.22	0.31	0.34	0.46	0.18	0.47	0.45	0.68	0.88	0.36	0.24
	(0.006)	(0.028)	(0.017)	(0.015)	(0.007)	(0.012)	(0.071)	(0.037)	(0.095)	(0.034)	(0.021)
Regional income (B1)	-0.51	0.06	-0.50	1.00	0.65	0.96	1.00	0.58	0.73	1.00	0.74
	(0.029)	(0.099)	(0.045)	(0.032)	(0.032)	(0.026)	(0.018)	(0.008)	(0.023)	(0.018)	(0.038)
Housing stock (B2)	1.51	0.94	1.50	0.00	0.35	0.04	0.00	0.42	0.27	0.00	0.26
	(0.029)	(0.099)	(0.045)	(0.032)	(0.032)	(0.026)	(0.018)	(0.008)	(0.023)	(0.018)	(0.038)
wages (B3)	5.04	3.14	3.46	1.17	4.83	1.19	1.21	0.88	0.41	1.81	3.50
	(0.130)	(0.258)	(0.174)	(0.073)	(0.203)	(0.057)	(0.365)	(0.083)	(0.144)	(0.272)	(0.417)
distance (B4)	-1.59	0.00	-1.77	-0.20	-0.71	0.00	-0.09	-1.49	-0.69	-0.09	-0.60
	(0.051)	(0.074)	(0.080)	(0.062)	(0.070)	(0.060)	(0.169)	(0.071)	(0.154)	(0.071)	(0.072)
Obs.	29975	30691	31099	31099	38322	38322	33489	33141	34053	37069	33447
Adj. R^2	0.78	0.34	0.62	0.88	0.76	0.50	0.00	0.50	0.30	0.59	0.52
Log likelihood	50542	11404	9812	27349	38273	32499	6493	18300	13381	35874	15883
AIC	-101077	-22803	-19619	-54692	-76541	-64992	-12980	-36594	-26756	-71743	-31761
BIC	-101052	-22778	-19594	-54667	-76515	-64967	-12955	-36569	-26730	-71717	-31735

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 4. Nonlinear Least Square Estimation Results for My Wage Equation without Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	2.41	3.07	2.73	2.99	2.23	2.31	5.24	1.50	1.03	1.37	1.03
	(0.008)	(0.045)	(0.032)	(0.027)	(0.012)	(0.015)	(0.162)	(0.006)	(0.000)	(0.002)	(0.000)
τ	0.10	0.06	1.10	0.08	0.10	0.11	2.56	0.02	0.20	0.13	0.16
	(0.001)	(0.002)	(0.029)	(0.001)	(0.001)	(0.001)	(0.096)	(0.000)	(0.003)	(0.001)	(0.002)
μ	0.91	0.82	0.97	0.89	0.90	0.92	1.00	0.46	0.88	0.89	0.84
	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.003)	(0.001)	(0.001)	(0.002)
b	0.93	0.95	0.97	0.95	0.92	0.94	0.99	0.72	0.80	0.89	0.84
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)	(0.002)	(0.001)	(0.002)
Implied values											
Market potential	0.41	0.33	0.37	0.33	0.45	0.43	0.19	0.67	0.97	0.73	0.97
	(0.001)	(0.005)	(0.004)	(0.003)	(0.002)	(0.003)	(0.006)	(0.002)	(0.000)	(0.001)	(0.000)
Regional income (B1)	0.84	0.52	0.94	0.75	0.86	0.88	0.99	0.19	0.99	0.95	0.99
	(0.001)	(0.012)	(0.002)	(0.004)	(0.002)	(0.002)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
Housing stock (B2)	0.16	0.48	0.06	0.25	0.14	0.12	0.01	0.81	0.01	0.05	0.01
	(0.001)	(0.012)	(0.002)	(0.004)	(0.002)	(0.002)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
wages (B3)	1.68	2.65	1.84	2.34	1.48	1.52	4.28	1.50	0.05	0.47	0.05
	(0.009)	(0.053)	(0.034)	(0.031)	(0.014)	(0.016)	(0.164)	(0.014)	(0.000)	(0.003)	(0.000)
distance (B4)	-0.14	-0.13	-1.91	-0.17	-0.12	-0.14	-10.87	-0.01	-0.01	-0.05	-0.01
	(0.001)	(0.004)	(0.049)	(0.003)	(0.001)	(0.002)	(0.358)	(0.000)	(0.000)	(0.000)	(0.000)
Capital return (B5)	-0.05	-0.03	-0.02	-0.04	-0.05	-0.04	-0.01	-0.13	-0.01	-0.04	-0.01
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
Real wage (B6)	-0.70	-0.86	-0.67	-0.79	-0.66	-0.66	-0.82	-1.00	-0.05	-0.34	-0.04
	(0.002)	(0.006)	(0.004)	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.000)	(0.001)	(0.000)
Obs.	29975	30691	31099	31099	38322	38322	33489	33141	34053	37069	33447
Adj. R^2	0.77	0.39	0.62	0.90	0.76	0.52	0.05	0.48	0.27	0.61	0.51
Log likelihood	50289	12545	9778	30776	38388	33448	7341	17868	12630	36868	15417
AIC	-100570	-25082	-19548	-61543	-76769	-66887	-14675	-35728	-25253	-73727	-30825
BIC	-100537	-25049	-19515	-61510	-76734	-66853	-14641	-35695	-25219	-73693	-30792

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 5. Nonlinear Least Square Estimation Results for Hanson's Wage Equation with Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	3.58				5.95	3.02	4.95	1.57	6.24	8.68	4.12
	(0.045)				(0.116)	(0.091)	(0.274)	(0.032)	(0.399)	(0.191)	(0.209)
τ	0.84				0.35	0.01	2.27	3.24	0.00	0.11	0.20
	(0.020)				(0.011)	(0.005)	(0.151)	(0.192)	(0.001)	(0.005)	(0.015)
μ	0.73				0.93	1.00	1.00	0.61	0.93	1.00	0.91
	(0.004)				(0.003)	.	.	(0.013)	(0.008)	.	(0.004)
Implied values											
Market potential	0.28				0.17	0.33	0.20	0.64	0.16	0.12	0.24
	(0.003)				(0.003)	(0.010)	(0.011)	(0.013)	(0.010)	(0.003)	(0.012)
Regional income (B1)	0.06				0.65	1.00	1.00	0.63	0.63	1.00	0.70
	(0.017)				(0.016)	(0.000)	(0.000)	(0.010)	(0.041)	(0.000)	(0.020)
Housing stock (B2)	0.94				0.35	0.00	0.00	0.37	0.37	0.00	0.30
	(0.017)				(0.016)	(0.000)	(0.000)	(0.010)	(0.041)	(0.000)	(0.020)
wages (B3)	3.52				5.29	2.02	3.95	0.94	5.62	7.68	3.42
	(0.054)				(0.123)	(0.091)	(0.274)	(0.036)	(0.404)	(0.191)	(0.223)
distance (B4)	-2.17				-1.75	-0.03	-8.97	-1.85	0.00	-0.83	-0.63
	(0.048)				(0.051)	(0.010)	(0.419)	(0.088)	(0.004)	(0.040)	(0.053)
Obs.	18696				26345	29853	27945	27294	27160	30518	27847
Adj. R^2	0.903				0.806	0.511	0.019	0.496	0.308	0.636	0.507
Log likelihood	39226.3				29752.1	25642.7	4035.75	14396.4	8781.74	31168.4	11598.1
AIC	-78440.6				-59492.3	-51275.4	-8061.49	-28780.8	-17551.5	-62326.7	-23184.2
BIC	-78393.6				-59443.2	-51233.9	-8020.3	-28731.5	-17502.2	-62285.1	-23134.8

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

Table 6. Nonlinear Least Square Estimation Results for My Wage Equation with Wage Control

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
σ	1.97				2.10	2.44	4.92	1.53	1.07	1.48	1.05
	(0.004)				(0.011)	(0.019)	(0.175)	(0.007)	(0.001)	(0.003)	(0.001)
τ	0.10				0.10	0.10	2.25	0.02	0.18	0.13	0.15
	(0.000)				(0.001)	(0.001)	(0.098)	(0.000)	(0.003)	(0.001)	(0.002)
μ	0.91				0.90	0.92	1.00	0.61	0.88	0.90	0.85
	(0.000)				(0.001)	(0.001)	(0.000)	(0.003)	(0.002)	(0.001)	(0.002)
b	0.91				0.92	0.94	0.99	0.65	0.85	0.89	0.81
	(0.000)				(0.001)	(0.001)	(0.000)	(0.003)	(0.003)	(0.001)	(0.003)
Implied values											
Market potential	0.51				0.48	0.41	0.20	0.65	0.93	0.68	0.95
	(0.001)				(0.002)	(0.003)	(0.007)	(0.003)	(0.001)	(0.002)	(0.000)
distance (B4)	-0.10				-0.11	-0.15	-8.82	-0.01	-0.01	-0.06	-0.01
	(0.000)				(0.001)	(0.002)	(0.351)	(0.000)	(0.000)	(0.000)	(0.000)
Regional income (B1)	0.89				0.87	0.86	0.99	0.47	0.99	0.94	0.99
	(0.001)				(0.001)	(0.002)	(0.001)	(0.007)	(0.000)	(0.001)	(0.000)
wages (B3)	1.18				1.33	1.66	3.95	1.35	0.10	0.60	0.08
	(0.005)				(0.012)	(0.021)	(0.176)	(0.014)	(0.001)	(0.004)	(0.001)
Housing stock (B2)	0.11				0.13	0.14	0.01	0.53	0.01	0.06	0.01
	(0.001)				(0.001)	(0.002)	(0.001)	(0.007)	(0.000)	(0.001)	(0.000)
Capital return (B5)	-0.05				-0.05	-0.04	0.00	-0.19	-0.01	-0.04	-0.01
	(0.000)				(0.000)	(0.001)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
Real wage (B6)	-0.60				-0.63	-0.68	-0.80	-0.88	-0.09	-0.40	-0.07
	(0.001)				(0.003)	(0.003)	(0.007)	(0.006)	(0.001)	(0.002)	(0.001)
Obs.	18696				26345	29853	27945	27294	27160	30518	27847
Adj. R^2	0.89				0.81	0.53	0.03	0.48	0.28	0.64	0.49
Log likelihood	38139				29738	26218	4192	14067	8163	31446	11224
AIC	-76264				-59461	-52422	-8369	-28120	-16312	-62879	-22434
BIC	-76209				-59404	-52364	-8312	-28063	-16255	-62820	-22376

Source: Author's calculations based on data in *China Statistical Yearbook* and *China City Statistical Yearbook* (1990-2001)

APPENDIX
HANSON (2005)'S REGRESSION RESULTS

Hanson's estimation of the wage equation based on Krugman's model

Time period	1970–1980 (1)	1980–1990 (2)	1970–1980 (3)	1980–1990 (4)	1980–1990 (5)	1980–1990 (6)
Market potential	0.132	0.152	0.132	0.147	0.203	0.203
	(0.022)	(0.020)	(0.258)	(0.021)	(0.056)	(0.056)
Distance	−12.993	−17.907	−11.580	−17.561	−6.430	−6.429
	(1.071)	(0.906)	(1.006)	(0.953)	(0.520)	(0.520)
Personal income	0.394	0.802	0.381	0.805	0.931	0.931
	(0.076)	(0.068)	(0.095)	(0.084)	(0.128)	(0.128)
Wages	7.202	5.760	6.997	5.974	4.004	4.006
	(1.271)	(0.823)	(1.439)	(0.953)	(1.313)	(1.314)
Housing stock	0.606	0.198	0.619	0.196	0.069	0.068
	(0.076)	(0.068)	(0.095)	(0.084)	(0.128)	(0.128)
Implied values						
σ	7.597	6.562	7.377	6.779	4.935	4.937
	(1.250)	(0.838)	(1.402)	(0.973)	(1.372)	(1.372)
τ	1.970	3.219	1.816	3.039	1.634	1.633
	(0.328)	(0.416)	(0.351)	(0.440)	(0.523)	(0.523)
μ	0.916	0.956	0.911	0.967	0.982	0.983
	(0.015)	(0.013)	(0.018)	(0.016)	(0.035)	(0.035)
$\sigma/(\sigma-1)$	1.152	1.180	1.157	1.173	1.254	1.254
	(0.029)	(0.030)	(0.034)	(0.029)	(0.089)	(0.089)
$\sigma(1-\mu)$	0.639	0.226	0.653	0.221	0.085	0.084
	(0.072)	(0.075)	(0.089)	(0.094)	(0.158)	(0.158)
Adj. R^2	0.256	0.347	0.217	0.296	0.376	0.376
Log likelihood	−16,698.1	−16,576.9	−14,699.4	−14,662.2	−16,479.9	−14,573.0
Schwarz criterion	−16,714.0	−16,592.9	−14,715.0	−14,677.9	−16,575.5	−14,667.1
Wald test (p-value)	0.000	0.000	0.000	0.000	0.001	0.001
Counties	All	All	Low pop.	Low pop.	All	Low pop.
Wage controls	No	No	No	No	Yes	Yes

Hanson's estimation of the wage equation based on Helpman's model

Time period	1970–1980 (1)	1980–1990 (2)	1970–1980 (3)	1980–1990 (4)	1980–1990 (5)	1980–1990 (6)
(α_1) market potential	0.487	0.393	0.492	0.488	0.467	0.573
	(0.119)	(0.164)	(0.119)	(0.207)	(0.372)	(0.271)
(α_2) distance	−11.163	−15.400	−11.145	−16.597	−16.175	−15.108
	(2.081)	(2.054)	(2.082)	(3.312)	(3.453)	(2.366)
(α_3) personal income	0.120	0.664	0.121	0.615	0.834	0.754
	(0.046)	(0.138)	(0.046)	(0.127)	(0.338)	(0.169)
(α_4) wages	1.934	1.882	1.908	1.435	1.306	0.992
	(0.519)	(0.957)	(0.509)	(0.770)	(1.398)	(0.703)
(α_5) housing stock	0.880	0.336	0.879	0.385	0.166	0.246
	(0.046)	(0.138)	(0.046)	(0.127)	(0.338)	(0.169)
Implied values						
σ	2.053	2.546	2.028	2.050	2.140	1.745
	(0.500)	(1.064)	(0.490)	(0.869)	(1.705)	(0.827)
τ	10.593	9.964	10.836	15.800	14.188	20.272
	(5.585)	(7.129)	(5.737)	(14.901)	(18.875)	(20.626)
μ	0.545	0.821	0.539	0.732	0.873	0.752
	(0.113)	(0.154)	(0.114)	0.218	(0.385)	(0.317)
$\sigma/(\sigma-1)$	1.934	1.647	1.972	1.950	1.877	2.341
	(0.519)	(0.446)	(0.463)	(0.787)	(1.312)	(1.488)
$\sigma(1-\mu)$	0.935	0.456	0.935	0.550	0.272	0.433
	(0.025)	(0.210)	(0.025)	(0.221)	(0.614)	(0.359)
Adj. R^2	0.160	0.314	0.159	0.298	0.327	0.309
Wald test (p-value)	0.000	0.000	0.000	0.000	0.015	0.002
Chi-square (p-value)	0.343	0.200	0.254	0.167	0.206	0.327
Instrument set	Narrow	Narrow	Broad	Broad	Narrow	Broad
Wages controls	No	No	No	No	Yes	Yes

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