TALENT, TECHNOLOGICAL INNOVATION AND ECONOMIC GROWTH IN CHINA

TAIRAN LI AND RICHARD FLORIDA*

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Abstract

China's economic development over the past 20 years has been nothing short of astonishing. Scholarly research and popular commentary alike have attributed this dramatic growth record to China's large market and low costs, especially in manufacturing. More recent accounts have noted China's significant rate of talent production, particularly of scientists and engineers, and its emerging ability to generate technological innovation and attract the research and development facilities of large multinational firms as well. Yet few studies have examined the regional underpinnings of Chinese development and none to our knowledge have systematically explored regional differences in talent, technology, and economic growth.

This article explores the economic geography of talent and technology in China and their effects on economic growth. It further examines the effects of non-market factors such as amenities and diversity on talent, technology and growth. It introduces unique measures of talent production, amenities and diversity that reflect the particularities of the Chinese case; and examines the relationships between these factors, technological innovation, and regional economic growth via multivariate regression analysis and path analysis (as per Florida 2002c).

The findings show that the production of talent is highly uneven and concentrated in China, as is technological innovation and economic growth. They further indicate that talent production in China is shaped both by quality-of-life factors (amenities) and low barriers to entry (diversity), and also that regional differences in talent production have a significant effects on technological innovation and consequently economic growth. Talent production, technological innovation, and economic growth in China are tremendously concentrated, taking place in a small number of major urban centers.

Key Words: Talent, diversity, amenity, human capital, high-technology industry.

Introduction

China's economic development record over the past few decades has been remarkable. Both scholarly research and popular commentary have noted the nation's meteoric rise as a powerful new economic competitor. In the main, it is argued that Chinese development has turned on the nation's huge market and low costs, especially in manufacturing. But more recent commentators note China's rapidly rising rate of human capital production, particularly its huge and growing production of scientists and engineers, alongside rising investments in its universities and academic infrastructure and its growing ability to conduct research and development and attract the R&D affiliates of foreign multinationals. But few if any analyses have focused on the regional underpinnings of Chinese development and none to our knowledge has focused on regional differences in the production and use of human capital or talent.

Yet economics research on the United States and other advanced nations shows that there are significant regional differences in the levels of human capital and technology. A huge body of research has documented the effect of technology and human capital on economic growth at the national and regional scales. Solow's (1957) noted the effect of technology on economic growth; subsequent research has found considerable regional differences in the level and utilization of innovation and high-tech industry (Markusen et al 1986; DeVol 1999). Ullman (1958) long ago noted the role of human capital in his classic work on regional development. The endogenous growth model developed by Lucas (1988) further clarified the role of human capital externalities in economic development. More recent research (Glaeser et al 1995; Glaeser 1998, 1999, 2000; Simon 1998) has empirically verified the role of human capital in regional growth. Florida (1999, 2000, 2002a, 2002b, 2002c, 2005) has noted the considerable differences in human capital across regions and has argued for the need to better understand the factors that not only produce human capital but which enables regions to attract it, suggesting that human capital operates less as a static endowment or stock and more as a dynamic flow. Glaeser and Berry (2005) have documented the growing divergence in human capital levels across U.S. regions over the past three or four decades.

While technology and talent have been shown to be strongly associated with economic growth and development, far less research has been done on the factors that enable regions to produce and attract talent and generate new technology. The literature has identified three classes of factors that can affect the distribution, level and flow of human capital across regions. The traditional urban economics literature argues that talent is attracted to the availability of employment opportunities and financial rewards. More recent research identifies two additional non-market factors that affect the level and flow of human capital. Operating on the consumption-side, quality-of-life or urban amenities have been found to matter in the location decisions of high human capital households (Glaeser, Kolko, and Saiz 2001; Lloyd 2001; Lloyd and Clark 2001). Florida (1999, 2000, 2002a, 2002b, 2002c, 2005; Florida and Gates 2001) has argued that talent is also attracted to regions that offer low barriers to entry and higher levels of openness and tolerance, measured, for example, by the concentrations of new immigrants and gay and lesbian populations.

This article explores the economic geography of talent and technology in China, the factors that shape that geography, and the effects of each on regional economic growth. It examines these factors across China's 100 largest city-regions. The research introduces a novel measure for talent production, an index based upon the number of leading universities in each region. While we would have liked to utilize additional measures of talent such as educational attainment or occupational structure, these measures are not available on a systematic basis for Chinese regions. This university-based measure is a good proxy for talent attraction and production in China, where the major migration of talent occurs from high school to university, as students tend to migrate from rural to urban centers and to remain in those same urban centers after graduation. The research also introduces novel measures of quality-of-life and diversity, which reflect the unique conditions and characteristics of the Chinese case, and examines their effects on talent and technology in China. We conduct bivariate analysis and multivariate regressions to examine the factors that shape the economic geography of talent production and technological innovation, and to gauge the effects of each of them on regional growth and development. Following Florida (2002c), we also use path analysis to further detail the nature of the relationships among the key variables in our model.

The findings show that talent production and technological innovation in China are highly concentrated and uneven. The top ten Chinese regions house 16 percent of its population but account for a third of its Gross Domestic Product, 43 percent of its talent-producing universities, and 58 percent of technology. Its top 50 regions, which house roughly half of the population, account for 80 percent of GDP, 90 percent of talent, and 95 percent of technological innovation. The findings further indicate that regional economic growth in China follows a distinct structure with talent production operating as a critical intermediate variable. Talent production is strongly associated with both leisure-oriented amenities and openness to diversity. It is important to note that talent production is not a function of city size, as our measure for talent production is not associated with population. In our view, each of these factors plays a distinctive role. Amenities operate on the consumption side to attract talent to a region, while openness to diversity works to lower barriers to entry for different demographic groups, increasing the pool of potential talent and facilitating the flow of talent into the region. Talent in turn operates on regional growth principally by affecting the level of technological innovation which in turns shapes growth.

Theory and Concepts

Technology and talent have long been seen as driving forces of economic growth. Solow (1957) long ago argued that economic growth relies upon technological change. Jacobs (1961, 1969) focused on the transfer of knowledge in cities. In her view, cities play a crucial role in economic development through the interaction among people and the generation of new products and new technology. Romer (1986) established the connection between knowledge, human capital, and economic growth through his endogenous growth model, arguing that investments in human capital generate spillovers and increasing returns. The seminal Lucas (1988) endogenous regional model noted that cities function to transfer knowledge and generate powerful human externalities that increase productivity and spur growth. The connection between human capital and regional growth is supported by a wide body of empirical evidence at the national and regional levels. Barro (1991) found a close relationship between human capital and economic growth at the country level. A large number of studies have found strong relationships between human capital and regional growth (Glaeser et al 2000; Rauch 1994; Young 1995; Eaton and Eckstein 1997; Black and Henderson 1999; Simon 1998; Glendon 1998; Shapiro 2003.

There is considerably less research on the factors associated with the regional distribution of talent. One line of research suggests that talent is attracted by quality-of-life factors or amenities (Glaeser, Kolko, and Saiz 2001; Lloyd 2001; Lloyd and Clark 2001). Florida (2002) found a positive relationship between technological creativity (measured by innovation and high-technology GDP) and cultural creativity (measured by what he called the "bohemian index"). Another line of research argues that talent is attracted to openness to diversity. Urban and regional economists have long argued that diversity is important to regional economic growth. Jacobs (1968) particularly emphasized the role of urban diversity and immigration in the formation of new ideas. Following Jacobs' lead, Glaeser et al. (1992) present evidence suggesting that urban diversity and competition is good for growth. Quigley (1998), Desrochers (2001), and Zachary (2000) all suggest that regional economies benefit from the location of a diverse set of firms and industries and openness to immigration. Henderson et al. (1995), however, suggests that the diversity - growth connection is far less clear. Others have examined the effects of diversity on human capital, suggesting that more open and diverse regions are able to attract from a larger talent pool. Saxenian (1999) found that skilled immigrants were a growing presence in Silicon Valley, accounting for one-third of the engineering workforce in most technology firms in 1990s. Florida (1999, 2000, 2002a, 2002b, 2002c, 2005; Florida and Gates 2001) found a significant relationship be-

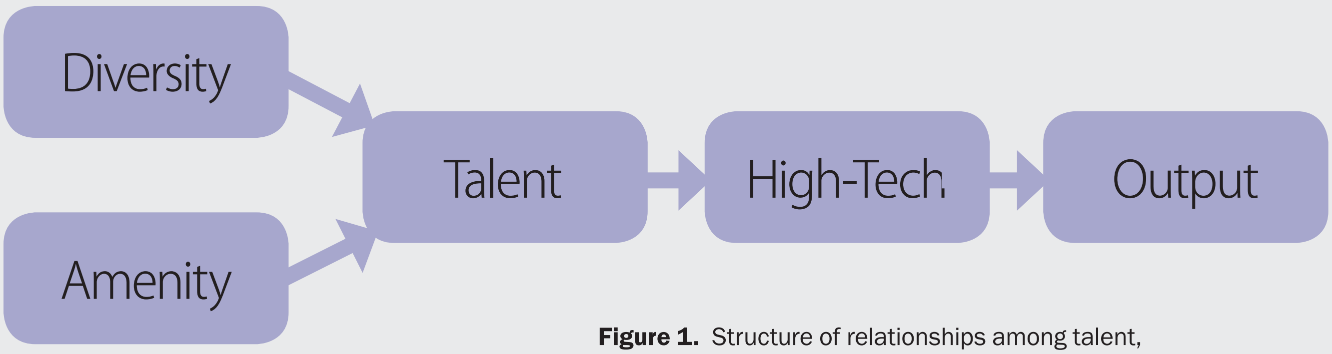


Figure 1. Structure of relationships among talent, technological innovation and growth.

tween the level of immigration and regional growth for small and medium-size regions and between the level of the gay population and growth in large regions. He theorized that diversity acts on innovation and growth by creating low barriers to entry for talent, thereby increasing the potential for talent to flow into a region.

This article argues that talent production plays a critical intermediate role in shaping regional and overall national growth in China. Figure 1 details the general structure of our model, which provides a stage-based model of economic growth. This model, we argue, is a considerable advance over typical empirical growth models, which essentially lump a wide variety of factors and variables into a single linear regression format. Our model suggests that the structure of economic growth occurs in three distinct but interrelated phases which connect and clarify the independent effects of three types of factors on economic growth: (1) non-market factors such as amenities, quality-of-life and diversity identified by Jacobs, Glaeser, Clark and Florida, (2), talent and human capital externalities identified by Romer, Lucas and Glaeser, and (3) technological change as identified by Solow and Romer. In the first stage of the model, non-market or sociological factors such as quality of life, amenity and diversity (identified by Jacobs, Florida, Glaeser and Clark) shape the ability of places to produce, attract and retain talent. The ability of a city or region to produce and attract talent is not simply a result of its employment opportunities or its population size, but is shaped by quality-of-life factors and lower barriers to entry (diversity). In the second stage of the model, higher levels of talent generate the human capital spillovers and externalities identified by Jacobs and Lucas, leading to greater levels of technological innovation. In the third stage of the model, higher levels of technological innovation of the sort identified by Solow and Romer lead ultimately to higher levels of regional output and growth. We test these relationships through multivariate regression and path analysis.

Data, Variables and Methodology

To empirically test the structure of these relationships, we collected systematic data on amenities and diversity, talent and technological innovation, and regional economic growth for China 's 100 largest city-regions – that is, city-regions with populations of 4.5 million or greater. These city-regions are home to roughly 700 million people, or roughly 55 percent of China's total population of 1.3 billion people.

Non-Market Factors: Four measures are used to assess non-market factors. The first two are essentially measures of quality-of-life or amenity: average temperature and recreational amenities (measured as the total number of "well-known" parks, museums, and historical sites, available at http://www.itsqq.com/a/Index.html). These factors are exogenous, as such amenities and historical sites normally have a long history and are not therefore determined by other factors. The third and fourth are measures of diversity or low barriers to entry for talent. The first is a measure of minority population. There are 56 nationalities in China, and minorities made up 8 percent of the total population in 2004; total minority types by region were used to compute this Minority Index.

The final measure is a dummy variable for the languages spoken in a region. In China, Mandarin is the official language, and spoken in most northern cities. Varieties of dialects are often used in southern cities, and enriched by their local cultures. Since Mandarin is spoken by most Chinese people, regions where residents communicate in Mandarin will have relatively low barriers to entry. The value of 1 is representative of a city in which most people speak Mandarin, and zero of a city in which most people speak dialects. The boundary between Mandarin and a dialect is often blurred, as few people speak pure Mandarin or pure dialect. Comparison between them is inevitably judgmental, and degrees of differences are considered. The diversity measures are also exogenous, as they, too, are historical indicators in nature and measure the openness of a region.

Talent Production: Talent is measured as a proxy index of the number of universities per capita in each city. While we would have preferred to use a measure for educational attainment (such as the percent of the population with a bachelor's degree and above) or of occupational structure, such data are unavailable for Chinese regions. However, in China going to college is one of the most important ways that talented people relocate themselves from poorer rural areas to rapidly growing urban centers. In contrast to the United States, where mobility among college graduates is great, most Chinese students tend to remain (to work) in the same city-regions where they went to college. As such, we believe this index is a good proxy for highly educated, high human capital people.

Technological innovation: The measure of technological innovation is based on the city's total amount of invention patents approved by the State Intellectual Property Office of China before September 20, 2005.

Regional Output: We also include data for regional output in absolute terms for the year 2004.

Table 1 summarizes the key descriptive statistics for these variables.

Table 1. Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Diversity	100	37.51	9.08	20	55
Technological Innovation	100	5,514.75	12,282.03	96	96,653
Talent Production	100	0.65	0.80	0.094	3.618
Regional Product	100	108.35	107.13	21.45	745.03
Language	100	0.38	.49	0	1
Temperature	100	15.27	4.15	2.4	23.7
Recreational amenities	100	36.15	68.76	3	675

The research utilized a series of statistical and econometric techniques. We conducted bivariate and multivariate regressions of talent, technology and regional growth in China. Following Florida (2002c), we also used path analysis to further detail the nature of the relationships among the variables in our stage-based model outlined above.

Findings

Talent, technology and regional output in China are all highly concentrated and uneven. As Table 2 shows, China's top 10 city-regions, which account for 16 percent of its population, account for 43 percent of talent production and 58 percent of technological innovation. Its top 25 regions, which house 30 percent of its people, account for nearly three quarters of talent production and more than 80 percent of technological innovations. And its top 50 regions, which house 52 percent of its population, account for nearly 90 percent of talent and 95 percent of technological innovation. Figure 2 illustrates the extreme concentration of China's economic assets on its eastern coast, providing a map of the major centers for university-based talent production in the coastal cities of Beijing, Nanjing, Wuhan, Guangzhou, Shenzhen, and Shanghai. In addition, as indicated in Table 2, talent is not associated with population.

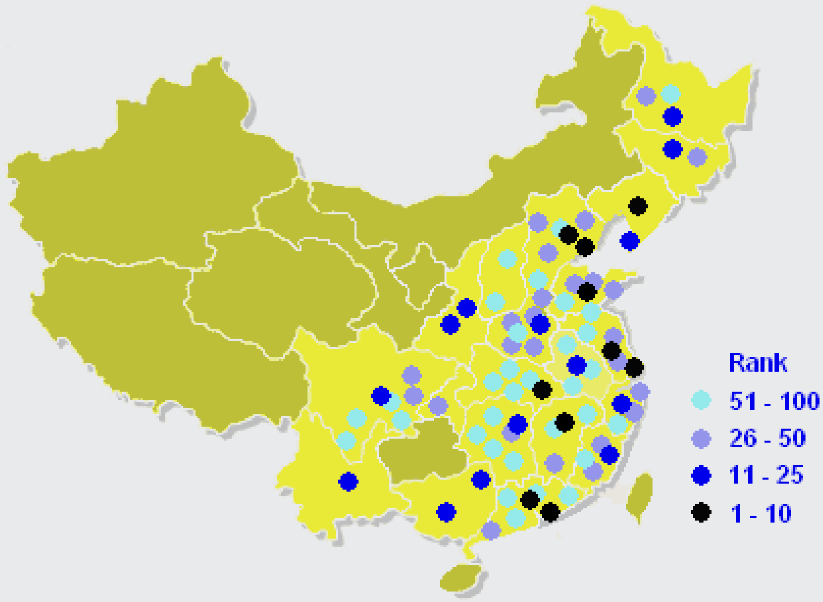


Table 2. The Geographic Distribution of Talent, Technology, and Regional Output

	Population	Talent	Technology	Regional Product
Top 10 Regions	16.02%	43.16%	57.95%	32.65%
Top 25 Regions	31.19%	73.08%	82.33%	57.17%
Top 50 Regions	52.11%	89.32%	94.54%	80.83%

Figure 2. The Economic Geography of Talent Production in China.
Source: Chinese Academy of Sciences, 2004

As noted above, we conducted statistical analyses to probe the structure of the relationships between non-market factors, talent, technology and economic growth in China. Table 3 summarizes the correlation coefficients for the key variables in out analysis. We discuss these results, along with the key findings from regression models, for talent production, technological innovation, and regional growth models below.

Table 3. Correlation Matrix for Key Variables

	Diversity	Technology	Talent	Output	Language	Temp.	Amenity
Diversity	1						
Technology	0.3827***	1					
Talent	0.3224***	0.7495***	1				
Output	0.4905***	0.7662***		1			
Language	0.1769*	0.1590	0.1410	0.0837	1		
Temperature	-0.0708	-0.0747	-0.0983	0.0402	-0.603***	1	
Amenity	0.2370**	0.8059***			0.0693	-0.0160	1
Population	0.3574***	0.3862***	0.1431		0.1272	-0.0217	

*Significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.01 level.

Talent Production:

The findings indicate that talent production is associated with non-market factors: amenities and diversity. The correlation coefficient for talent and amenities is positive and highly significant (0.459) while the correlation for diversity (measured as minority population) is 0.3224, lower than that for amenities but also highly significant. Figure 4 plots the relationship between talent production and amenities—note the position of Beijing as an extreme outlier on this graph, while Figure 5 does so for talent and diversity. These results reflect the findings that talented people are attracted to locations that have a high degree of amenity and diversity. The minority population measure index can be thought of as a indicator of these characteristics as places that are open to and supportive of minority populations, our proxy measure for diversity, are likely to be open and supportive of other groups.

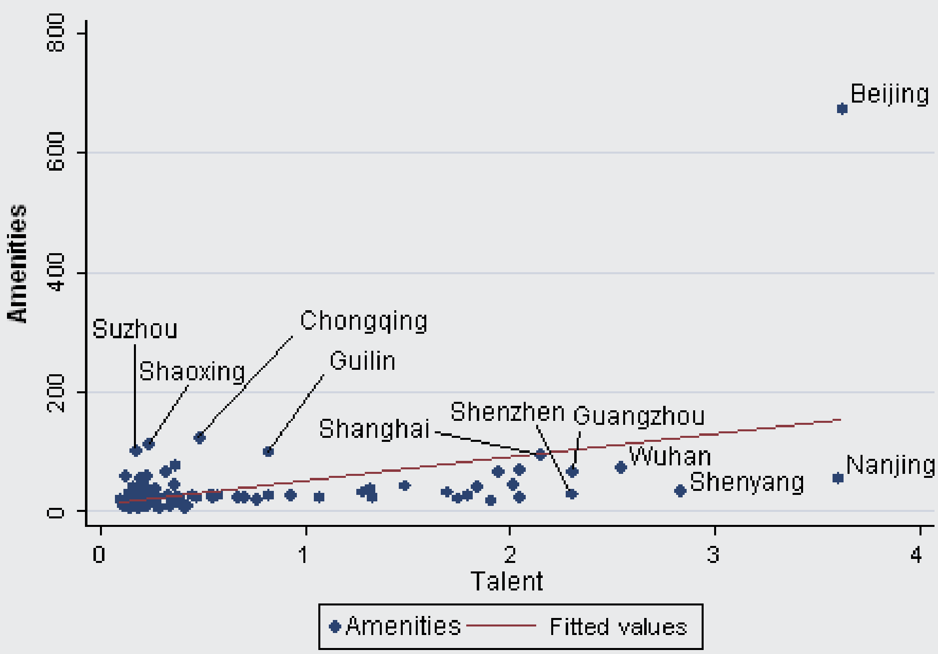


Figure 4. Scattergraph of Talent Production and Amenities.

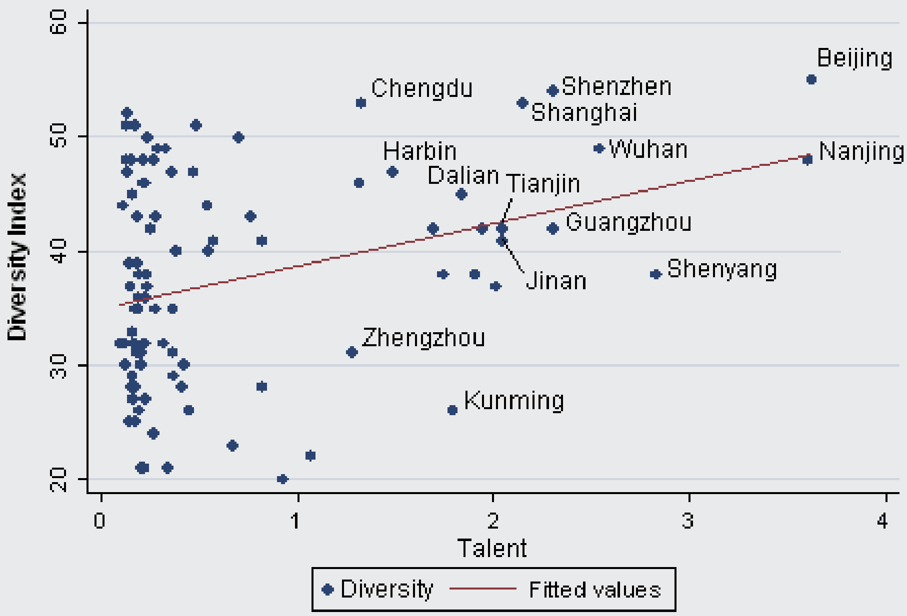


Figure 5. Scattergraph of Talent Production and Diversity (Minority Population).

However, neither climate nor language appears related to talent production, technological innovation or regional growth; the correlation coefficients for all are insignificant. The result for language may reflect the fact that people in those regions normally communicate with people from other regions in Mandarin, so the presence of dialects does not effectively raise the barrier. For example, people with all ethnic backgrounds can communicate with local people without difficulties in Shanghai, although it does have its own dialect completely distinct from Mandarin. Interestingly, while amenities and diversity are associated with city size, talent production is not—a point we elaborate on below.

Table 4 summarizes the findings for the regression models for talent production. These models generated adjusted R-squared values between 0.08 and 0.24 (see Table 4) and suggest that both diversity and amenity matter to the location of talent. The coefficient for the minority population variable is highly significant (at the 0.001 level) in the basic models where language and temperature are included, but less significant (at the 0.05 level) in more complex ones where amenity is included. This suggests that diversity (measured by the total number of minorities) is associated with the location of talent, but that the relationship between talent and amenity is even stronger.

Table 4. Regression 1: Determinants of Talent Production in China

	Dependent Variable: Talent					
	Model 1		Model 2		Model 3	
Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
Minorities	0.0270	0.00***	0.0189	0.02**	0.0214	0.01**
Language	0.1034	0.61	0.0736	0.69	0.0899	0.62
Temperature	-0.0073	0.75	-0.0095	0.66	-0.0083	0.70
Amenities			0.0047	0.00***	0.005	0.00***
Population					-0.0000	0.28
Observations	100		100		100	
R-squared	0.1121		0.2664		0.2753	
Adjusted R^2	0.0844		0.2355		0.2368	

*Significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.01 level.

There remains the obvious question of scale. Isn't it likely, one might argue, that major centers for talent and talent production, and also for amenities such as parks and recreation, will simply be larger city-regions? To test for this, we included population in our regressions. As Table 4 shows, the coefficient for population is positive but never significant. This finding indicates that talent production in China is not a function of larger population size.

Technological Innovation:

We now turn to the determinants of technological innovation in China. As Table 2 shows, technological innovation is closely correlated with talent production, as expected, with a coefficient of 0.7495 (significant at 0.001 level). Technological innovation is positively correlated with amenities (0.8059) and population (0.3862), but not with language (0.159), nor temperature (-0.0747). Technological innovation is also closely correlated with diversity (minority population) – a correlation coefficient of 0.3827 (significant at 0.001 level). Figure 5 is a scattergraph of the relationship between technology innovation and talent production, while Figure 6 shows the relationship between technological innovation and diversity (measured as minority population). Note that Beijing and Shanghai are extreme outliers on these graphs. *(next page)*

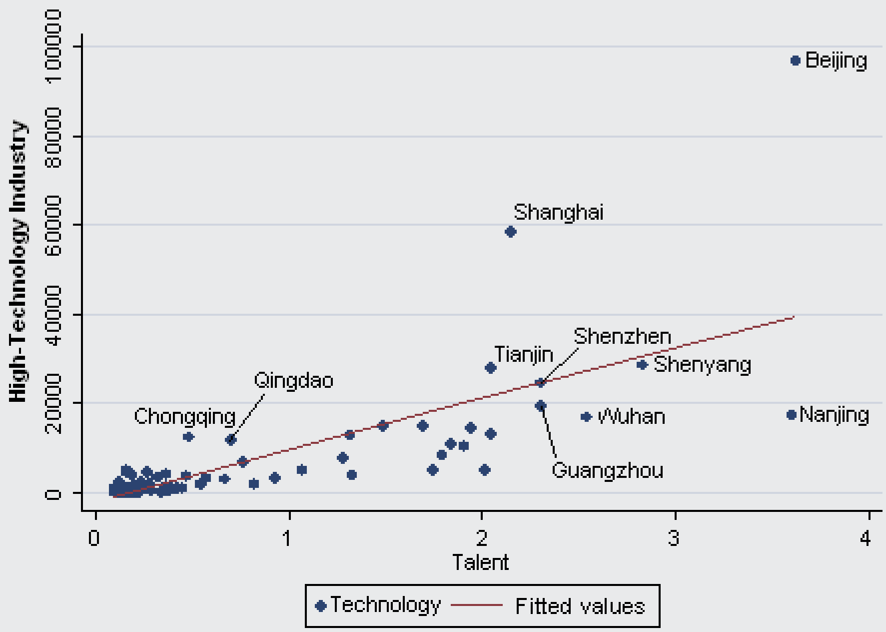


Figure 5. Scattergraph of Technological Innovation and Talent Production

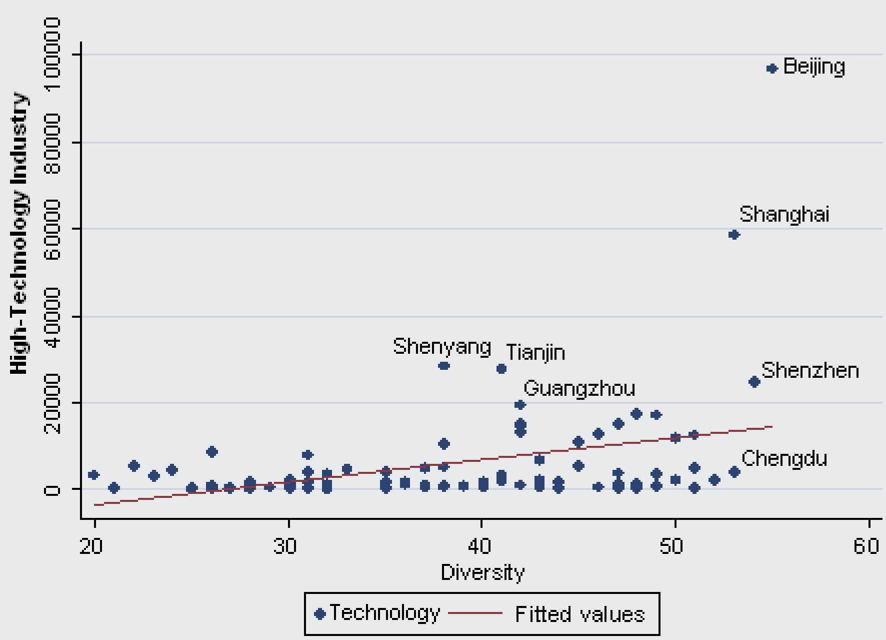


Figure 6. Scattergraph of Technological Innovation and Diversity (Minority Index)

A second series of regressions examined the determinants of technological innovation, using the measure of patents as the dependent variable (see Table 5). The adjusted R-squared values for these models range from 0.58 to 0.84. Technological innovation is associated with talent production in virtually all versions of the model, but only associated with diversity in models where population is not included. While scale effects do not appear to affect talent production, these findings indicate that they tend to matter for technology. Technological innovation is not associated with language or temperature; the coefficients for these variables are insignificant in all permutations of the model. In the basic structure of the model, where talent and minority population are included as the only independent variables, both are positive and significant. The adjusted R-squared for this model is 0.575.

However, technological innovation appears to be more associated with talent and amenity as both variables are highly significant in the third model, whereas minority population is only significant at 0.05 level. Interestingly, after population was added to the model, the effect of minority population becomes insignificant. Since the correlation between population and minority population is highly significant (0.3574; see Table 2), it appears that the effect of minority population on technology was partialled out by the effect of population, showing the effects of scale on technological innovation.

Table 5. Regression 2: Determinants of Technological Innovation in China

	Dependent Variable: Technological Innovation							
	Model 1		**Model 2**		**Model 3**		**Model 4**	
Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Diversity	212.89	0.025**	203.74	0.035**	127.36	0.035**	85.99	0.16
Talent	10775.18	0.000***	10742.61	0.000***	6944.31	0.000***	7123.06	
Language			1456.41	0.49	1198.17	0.36	945.36	0.47
Temperature			116.13	0.64	41.54	0.79	25.53	0.86
Amenities					102.45	0.000***	96.49	
Population							0.3947	0.028**
Observations	100		100		100		100	
R-squared	0.584		0.5861		0.8423		0.8503	
Adjusted R^2	0.575		0.5687		0.8340		0.8407	

*significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.01 level.

The nature of the relationship between technological innovation and talent production is straightforward. The ability to produce talent, especially from universities, is an increasingly important location factor for firms in highly competitive and highly innovative industries, where the speed with which new products are created is a critical success factor. Such knowledge-based firms and industries are less concerned with traditional factors, such as manufacturing costs, tax rates, and government incentives. Places able to attract and produce large talent pools reduce the costs associated with the search for talent, increase human capital externalities and spillover, and reduce the costs and increase the efficiency of the production and distribution of new ideas. Regions with lower barriers to entry for human capital, more diversity and greater amenities have the characteristics required to attract talent and generate technological innovations.

Regional Growth:

We now turn to the determinants of regional growth, employing total output as a dependent variable. There is substantial variation in outputs among the top 100 Chinese city-regions. As outlined above, output in China is highly concentrated, with the top 10 city-regions producing nearly third of all output, and the top 50 regions accounting for more than 90 percent of total output. The output of Shanghai exceeds 700 Billion Chinese Yuan, followed by Beijing and Guangzhou, both with output levels exceeding 400 Billion Chinese Yuan.

Talent production is positively correlated with output, a finding in line with the literature. The correlation coefficient between talent and output level (2004) is 0.6015 (high significant at 0.001 level). There is also a strong positive correlation between output and the diversity (minority population, 0.4905). This suggests that places open to a wider mix of people will not only attract talent, but tend to have higher output levels as well. Output is also positively associated with amenities and technological innovation. Again, Language and climate are not correlated with total output.

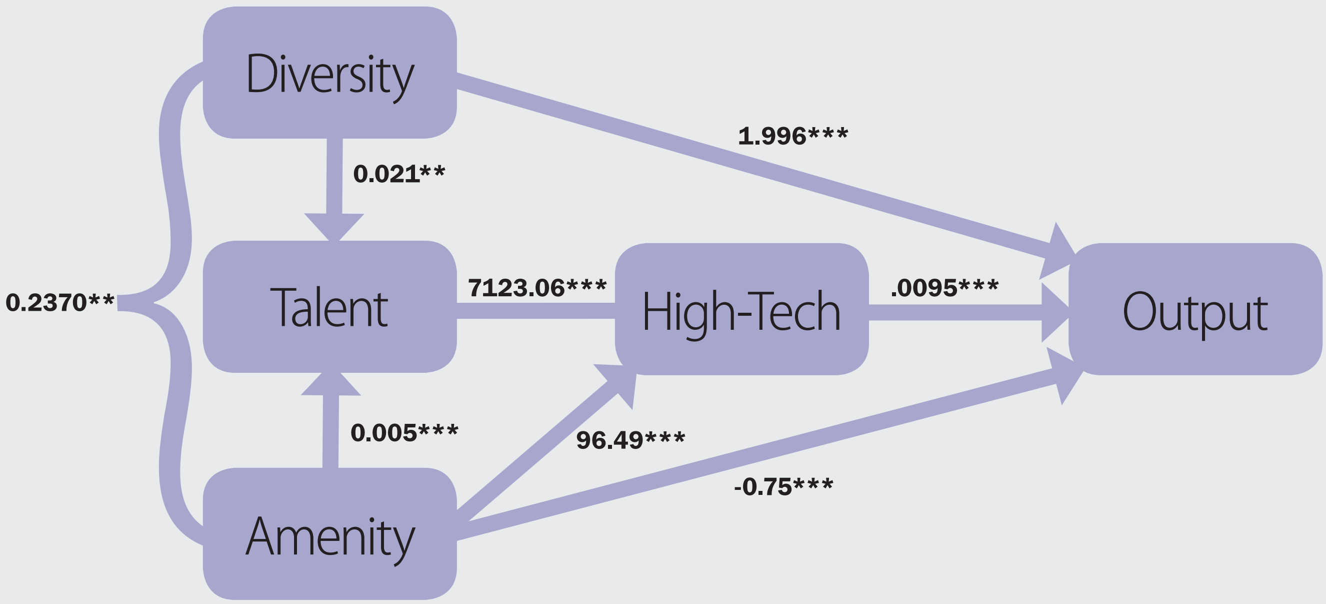
The third set of regressions examines the determinants of regional output (see Table 6). The adjusted R-squared values for these models are 0.62 and 0.70, respectively. The coefficient for minority population is positive and highly significant in all versions of the model. The coefficients for technology and amenity are also positive and significant in all models. However, the relationship between talent production and output is weak; talent is not associated with output. This comes as some surprise. What appears to be happening is that the effect of talent on output and per-capita output is being parceled out by technological innovations. It appears that talent operates as an intermediate variable that effects output indirectly through its effects on technological innovation. This provides an intellectual bridge of sorts, connecting Lucas-Glaeser-type human capital models to Solow-type technology models, a finding which we will elaborate on further when we discuss the results of path analysis, below.

Table 6. Regression 3: Determinants of Regional Output

	Dependent Variable: Output					
	Model 1		Model 2		Model 3	
Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
Diversity	2.7036	0.001***	2.4054	0.001***	1.9962	0.008***
Technology	0.0056	0.000***	0.0101	0.000***	0.0095	0.000***
Talent	5.8567	0.642	-13.43	0.272	-7.22	0.558
Language			-5.159	0.742	-7.41	0.630
Amenities			-0.742	0.000***	-0.751	0.000***
Climate			1.801	0.12	2.666	0.135
Population					0.0046	0.035**
Observations	100		100		100	
R-squared	0.6335		0.7129		0.7265	
Adjusted R^2	0.6221		0.6943		0.7057	

*Significant at the 0.10 level; **Significant at the 0.05 level; ***Significant at the 0.01 level.

Path Analysis: We conducted a path analysis to further probe the structure of relationships among the variables in our analysis. Recall that we conceptualize economic growth as a stage-based process, where: in stage 1, non-market factors like amenities and diversity affect the production and attraction of talent; in stage 2, talent affects the process of technological innovation; and ultimately, in stage 3, technological innovation affects economic growth. The results of the path analysis are summarized in Figure 6.



Note: *Significant at 0.10 level, **Significant at 0.05 level, ***Significant at 0.01 level

Figure 6: Path Analysis Results

The findings of the path analysis can be summarized in four main points. First, the path analysis indicates that non-market factors have a positive role in talent production and on other aspects of economic growth. Both diversity (measured as minority population) and amenities have positive direct effects. Diversity is not related to technology, but is related to output. It works indirectly on technological innovation via its effect on talent; this indirect effect is 152.43. Diversity works both directly and indirectly on output through two paths: talent and technological innovation. The indirect effect of diversity on output is 1.45, and the estimated total effect of diversity on output is 3.44. Amenity is directly related to technological innovation and output, as well as talent. Amenities have a positive direct effect (0.005) on talent. They have a positive direct effect (96.49) on technology, and a positive indirect effect through talent (35.62) as well. Interestingly, amenities have negative direct effect on output (-0.75), but a positive indirect effect through talent and technology (0.338) on output, as well as an indirect effect on output, which operates through technology (0.91). It is worth noting that the effects of the language and temperature variables were consistently weak across the board, which is in line with the findings of other analyses.

The second major finding is that talent plays a powerful role in technological innovation. Furthermore, while talent has no direct effect on output, it has a substantial indirect effect (67.67). Third, technological innovation has a powerful direct effect on output. Diversity is also significantly associated with output. Fourth, it should be pointed out that that population has a positive direct effect on technology (0.39, significant at 0.05 level), and it also has a positive direct effect on output (0.005). Here again we see that scale effects matter for innovation and output, but not for talent production.

The findings of the path analysis suggest the following structure of relationships among the variables, shedding light on key aspects of our stage-based model of economic growth. In stage 1, non-market factors such as diversity and amenity positively affect talent production; scale effects are weak as population does not affect talent. In stage 2, talent is associated with technological innovation, amenity matters, and scale effects operate to some degree. In stage 3, higher levels of technological innovation lead to greater regional output. Here, scale effects come into play, and diversity plays a role as well.

Conclusions

This article has explored the economic geography of talent and technology in China, the factors that shape that geography, and the effects of each on regional economic growth across the country's 100 largest city-regions. It conceptualized economic growth as a three stage process involving: (1) non-market factors i.e., amenities and diversity, (2) talent production, and (3) technological innovation. It introduced novel measures for talent production, diversity, and amenities that reflect data availability and the unique characteristics of the Chinese case, controlling for the effects of population or scale. It employed regression analysis to examine the factors that shape the economic geography of talent production and technological innovation, and to gauge the effects of each of them on regional growth and development. Following Florida (2002c), the research also used path analysis to further probe the nature of the relationships among key variables outlined in our regional growth model.

The findings show that talent production and technological innovation in China are highly concentrated and uneven. The top 10 Chinese regions house 43 percent of the universities which produce its top talent, and 58 percent of its technological innovations, while accounting for just 16 percent of its population. Its top 50 regions account for 80 percent of GDP, 90 percent of talent production, and 95 percent of technological innovation, while housing just slightly more than half its population.

The findings also have a number of important implications for research on economic growth. First and foremost, they suggest that we need to think about economic growth in China, and perhaps in emerging economies in general, less as a "national" phenomena and much more in terms of regional dynamics. As the Chinese case illustrates, talent production, technological innovation, and economic growth are all powered by a small number of large urban centers. It appears that regional differences in China, and perhaps in the emerging economies more generally, are considerably greater than the growing regional differences in human capital identified by Glaeser (2005) for the United States.

Second, the findings suggest that talent is a key variable in the economic growth of emerging as well as the advanced economies. The work of Jacobs (1961, 1969) and Lucas (1988) and the empirical findings of Glaeser (1998, 1999, 2000) all suggest that talent, or human capital, is a driving factor in regional development. Furthermore, talent is not just an endowment that is in place in a given region; it is more adequately conceptualized as a flow. Certain regional conditions appear to play a role in creating an environment or habitat that can attract and retain talent or human capital. Talent production is strongly associated with non-market factors: amenity and diversity. In our view, each of these factors plays a distinctive role. Amenities operate on the consumption side to attract talent to a region; while openness to diversity works to lower barriers to entry for different demographic groups increasing the possible pool of talent and facilitating the its inward flow. It is important to note that talent production is not a function of city size, as our measure talent production is not associated with population.

Third, the findings suggest that Chinese economic growth occurs through a stage based process as: (1) non-market factors condition talent production; (2) regional concentrations of talent effect technological innovation; and (3) technological innovation in turn affects economic output. These findings suggest that economic growth in China, and perhaps elsewhere, is the result of a cumulative process that involves a progression from non-market factors of the sort identified by Jacobs, Florida, Clark and Glaeser, to human capital externalities identified by Lucas, Romer and Glaeser, and the role of technological change noted by Romer and Solow. The findings further indicate that talent operates as a critical intermediate variable in the process of economic growth, connecting non-market factors to technological innovation and ultimately increased output.

We hope our findings stimulate increased debate and discussion about the nature of Chinese growth, and more generally about the process of economic development at the national and especially regional scales.

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