Elasticity-Growth Nexus in China's Great Expansion from the Perspective of Heterogeneous Labor

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Abstract: Highlighting skill difference rooted in heterogeneous labor, this paper employs SFA to estimate time-varying elasticity of substitution based on the panel data of Chinese provinces during 1996-2016, and further evaluate elasticity-growth nexus in ECM. Results show that it is both the capital-skill labor complementarity and the unskilled-skilled labor substitutability, rather than the capital-labor substitution proposed as the de La Grandville hypothesis, that develop into an engine of China's sustainable economic growth; to be more specific, the differentiating of heterogeneous labor plays an essential role in the evolution of factor substitution, which cannot be ignored especially in China's great expansion.

1. Introduction

The elasticity of substitution between labor and capital (σ) is an important determinant of an economy's long run performance. Ever since the elasticity-growth nexus, demonstrated by de La Grandville (1989) that a country with a higher σ could always achieve a higher rate of growth in transition, as well as a higher value of income per capita at steady state [1], has aroused a considerable interest both theoretical and empirical for two decades. Adding to these findings, Palivos and Karagiannis (2010) show more specifically that an elasticity of substitution, characterized as eventually greater than unity in convex growth models, is a powerful engine of growth due to counteracting the role of diminishing returns to capital, even in the absence of technical progress [2]. And subquently, a large number of empirical studies emerged in supportive of the Hypothesis of de La Grandville (Klump & de La Grandville, 2000; Sato & Morita, 2009; Mallick, 2012). However, Miyagiwa and Papageorgiou (2002), Irmen and Wigger (2003) found in Diamond overlapping-generations model, that a country with a greater exhibits lower per capita output growth in transit and in steady state[3]. Much further based on a cross-country empirical investigation, Duffy and Papageorgiou (2000) cautioned that σ is greater than unity is only a possibility but not sufficient for long-term perpetual growth to occur [4]. In summary, the study of elasticity-growth relationship has not yet reached a clear and agreed conclusion, so it needs to be further deepened and refined.

With China's rapid rise as the world's second largest economy, much attention has been attracted to its growth mechanism and sustainability. Especially under biased technological progress to estimate aggregate elasticity of substitution and to examine elasticity-growth interrelation has become hot issues in recent years. As for the aggregate elasticity of substitution, most studies applied the normalized CES supply-side system approach to estimate σ and ran this data of cross section of countries or industries to evaluate elasticity-growth nexus, and similar conclusions have been roughly reached that is in supportive of de La Grandville Hypothesis (Chen & Lian, 2012; Zheng Meng, 2016; Manu et al., 2018). However, Zheng and Yang (2015) calculated σ derived from VES production function and found that although the σ of each region is positively correlated with its regional growth, at the meanwhile, the growth rate of the East is higher than that of the West, the σ value of the West however, is higher than that of the East[5]. Thus, they claimed that the elasticity of capital-labor substitution can not determine the size of growth rate, that is, high σ does not mean high growth. As for the disaggregate elasticity of substitution, the purpose of current research is mostly to check "capital-skill complementarity hypothesis" proposed by Griliches (1969)

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to capture biased technical change, or to explore the relevant issues on skill premium or appropriate labor structure. Although these works have not been involved in the estimation of variable elasticity of substitution concerned with skill improvement of labor due to “learning by doing” in the process of industrialization, some of them confirmed that China’s technological progress is characterized by dual bias of capital and skilled labor, that is, there exists evident differentiation of labor internal structure. Different from the above studies, Zhang and Lin (2017) paid more attention to heterogeneous labor differentiating, a distinct feature of China as a populous country, and dug its impact, in form of variable elasticity of substitution derived from TLPF, on elasticity-growth nexus in regional perspective. Surprisingly, they found that the three regional cases are not satisfied empirically with de La Grandville hypothesis [6]. So far this paper gets an important inspiration that the heterogeneity of labor can not be ignored especially in China’s experiences when investigate the interact impact of substitution elasticity of subclasses factors on economic growth, and that would help us go further step on refining policy implications of an analysis among productive inputs.

2. Methodology

As pivotal technology parameters rooted in the production function, the substitution elasticities highly rely on the form of production function, that is, the appropriate production function and its estimation technique both play a decisive role in the follow-up calculation of substitution elasticities. This paper draws upon the work of Battese and Coelli (1995) who proposed the stochastic frontier production function model to analyze technical inefficiency effects. Specifically, here is as follow,

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_S \ln S_{it} + \beta_\tau \tau_{it} + \frac{1}{2}\beta_{\tau\tau}\tau_{it}^2 + \frac{1}{2}\beta_{KK}(\ln K_{it})^2 + \frac{1}{2}\beta_{LL}(\ln L_{it})^2 \\ &+ \frac{1}{2}\beta_{SS}(\ln S_{it})^2 + \beta_{KL}\ln K_{it}\ln L_{it} + \beta_{KS}\ln K_{it}\ln S_{it} + \beta_{LS}\ln L_{it}\ln S_{it} + \beta_{\tau K}\tau_{it}\ln K_{it} \\ &+ \beta_{\tau L}\tau_{it}\ln L_{it} + \beta_{\tau S}\tau_{it}\ln S_{it} + \nu_{it} - U_{it}\end{aligned} \quad (1)$$

Where the subscripts i and t refer to the i-th Chinese province and the t-th observed period, respectively; all the β letters depict unknown parameters to be estimated; Y_{it} donates output (local gross domestic product); K_{it} indicates capital input; labor input is disaggregated into unskilled (L_{it}) and skilled labor (S_{it}); the time variable τ is introduced to capture any technological change in the production function.

Turning to the inefficiency drivers, this paper focuses on the impact of heterogeneous human capital, the difference of technology absorptive capacity, as well as some institutional factors etc. Thus, the technical inefficiency effects nested in model (1) are specified with equation (2):

$$\begin{aligned}m_{it} &= \delta_0 + \delta_1 FDI_{it} + \delta_2 TRD_{it} + \delta_3 PMH_{it} + \delta_4 P_{it} + \delta_5 M_{it} + \delta_6 H_{it} + \delta_7 PMH_{it}\times TRD_{it} \\ &+ \delta_8 PMH_{it}\times FDI_{it} + \delta_9 P_{it}\times TRD_{it} + \delta_{10} M_{it}\times TRD_{it} + \delta_{11} H_{it}\times TRD_{it} + \delta_{12} P_{it}\times FDI_{it} \\ &+ \delta_{13} M_{it}\times FDI_{it} + \delta_{14} H_{it}\times FDI_{it} + \delta_{15} P_{it}\times M_{it} + \delta_{16} M_{it}\times H_{it} + \delta_{17} P_{it}\times H_{it}\end{aligned} \quad (2)$$

Where δ is the parameter to be estimated for the j-th explanatory variables related to provincial specific characteristics; FDI, TRD indicates the extent of foreign capital or trade reliance of each province; PMH denotes the aggregate human capital, while P, M, H proxy respectively the junior, the intermediate and the senior of human capital; PMH×TRD, P×FDI and P×M captures the technology absorbing capacity of heterogeneous human capital.

All the parameters β in the frontier function and δ in the inefficiency equation are generally evaluated in a single stage (Battese & Coelli, 1995) by running maximum likelihood estimate (MLE) to achieve both consistency and effectiveness. Once the estimated parameters are obtained, the substitute elasticities in different periods for each province can be calculated. First, the output elasticity with respect to input is computed:

$$\eta_{L_{it}} = \frac{\partial \ln Y_{it}}{\partial \ln L_{it}} = \beta_L + \beta_{LL} \ln L_{it} + \beta_{KL} \ln K_{it} + \beta_{LS} \ln S_{it} + \beta_{\tau L} t \tag{3}$$

$$\eta_{K_{it}} = \frac{\partial \ln Y_{it}}{\partial \ln K_{it}} = \beta_K + \beta_{KK} \ln K_{it} + \beta_{KL} \ln L_{it} + \beta_{KS} \ln S_{it} + \beta_{\tau K} t \tag{4}$$

$$\eta_{S_{it}} = \frac{\partial \ln Y_{it}}{\partial \ln S_{it}} = \beta_S + \beta_{SS} \ln S_{it} + \beta_{KS} \ln K_{it} + \beta_{LS} \ln L_{it} + \beta_{\tau S} t \tag{5}$$

Then the multi-factor elasticity of substitution is obtained respectively as (6), (7) and (8):

$$\sigma_{KL} = \left[1 + \left(2\beta_{KL} - \frac{\eta_L}{\eta_K}\beta_{KK} - \frac{\eta_K}{\eta_L}\beta_{LL} \right) (\eta_L + \eta_K)^{-1} \right]^{-1} \tag{6}$$

$$\sigma_{KS} = \left[1 + \left(2\beta_{KS} - \frac{\eta_S}{\eta_K}\beta_{KK} - \frac{\eta_K}{\eta_S}\beta_{SS} \right) (\eta_S + \eta_K)^{-1} \right]^{-1} \tag{7}$$

$$\sigma_{LS} = \left[1 + \left(2\beta_{LS} - \frac{\eta_L}{\eta_S}\beta_{SS} - \frac{\eta_S}{\eta_L}\beta_{LL} \right) (\eta_L + \eta_S)^{-1} \right]^{-1} \tag{8}$$

By performing the calculated data of time-varying elasticity of substitution in panel form, this paper then investigates the elasticity-growth nexus that sits in Cointegration Equation and in Error Correct Model. Suggested by Engle and Granger (1987), a two-step estimation procedure as follows:

$$\begin{aligned} RGDP_{it} &= \alpha_0 + \alpha_1 (\sigma_{KL})_{it} + \alpha_2 (\sigma_{KS})_{it} + \alpha_3 (\sigma_{LS})_{it} + \gamma_1 KLS_{it} \\ &+ \gamma_2 PMH_{it} + \gamma_3 TE_{it} + \gamma_4 FDI_{it} + \gamma_5 TRD_{it} + \upsilon_{it} \end{aligned} \tag{9}$$

$$DRGDP_{it} = \lambda_0 + \lambda_1 resid_{it-1} + \lambda_2 DRGDP_{it-1} + \sum_j \theta_j DX_{jit} + \varepsilon_{it} \tag{10}$$

Where RGDP represents the economic growth rate of each Chinese province, accordingly, DRGDP means the first difference of RGDP, others are the same; KLS indexes capital per capita; TE is provincial technology efficiency, derived from the stochastic frontier regression in the preceding steps; and $resid_{it-1}$ corresponds to the first lagged error in CE.

3. Data Description and Empirical Results Discussion

3.1 Indicators in the Stochastic Frontier Production Function

As shown in Formula (4), the dependent variable Y_{it} is provincial annual output measured in local Gross Domestic Product. In order to obtain comparable data across provinces and years, here GDP and the followed capital-stock deflators are both based on official price indexes, specifying 1952 as the base year. The aggregate inputs included as explanatory variables are: (a) capital stock K_{it} is estimated through a version of perpetual-inventory method assuming a $\delta_{it} = 10.96\%$ depreciation rate, which has drew on the experience of Shan Haojie (2008); (b) the input of unskilled labor is the sum number of employees with no education and primary schooling, while subtracting unskilled labor from the total workers input is skilled labor.

As for the technical inefficiency equation shown in Formula (5), as two important vehicles for transferring technology to host countries, FDI_{it} and TRD_{it} are measured as ratios to GDP separately; PMH_{it} is categorized by basic education (including not attending school and primary school), secondary education (including junior and senior high school), and advanced education (including college or higher education), all practitioners are correspondingly divided into three groups as the primary (P_{it}), the intermediate (M_{it}) and the high human capital (H_{it}), respectively. No schooling, primary school, junior high school, senior high school and college or above are recorded as 0, 6, 9, 12 and 16 schooling years separately. Thus, the human capital structure of each province is described by multiplying the proportion of the educational level of the employees in the "China Labor Statistics Yearbook" by the average schooling years.

3.2 Estimate of Production Function and Elasticity-Growth Nexus

Of particular note is my use of stochastic frontier analysis based on production theory, and the form of production function exerted to calculate elasticities of substitution has been strictly tested with China's provincial panel data, which ensures the accuracy and reliability of the estimated results. The test results display that the technical inefficiency in production is statistically significant, hence, one conclusion has confidently reached that it is the stochastic frontier function rather than the traditional production function more suitable for the analysis of China's aggregate production function. Then the final estimation of Translog Production Function (TLPF) is obtained in the form of China's country-wide level, which has been reported in Table 1.

Table 1 Maximum Likelihood Estimate on Tlpf (Mean Efficiency=0.695).

variable	Coefficient	Standard Error	t-ratio
Frontier Production Function			
beta 0 (intercept)	6.364***	0.957	6.647
beta 1 (lnK)	-1.343***	0.311	-4.315
beta 2 (lnL)	-1.081***	0.358	-3.016
beta 3 (lnS)	2.817***	0.400	7.040
beta 4 (t)	0.254***	0.044	5.752
beta 5 $(lnK)^2$	0.005***	0.001	5.969
beta 6 $(lnL)^2$	0.294***	0.034	8.766
beta 7 $(lnS)^2$	0.163***	0.045	3.653
beta 8 (t^2)	0.451***	0.055	8.237
beta 9 (lnK*lnL)	0.410***	0.065	6.326
beta 10 (lnK*lnS)	-0.705***	0.093	-7.590
beta 11(lnL*lnS)	-0.567***	0.092	-6.162
beta 12 (t*lnK)	-0.057***	0.008	-6.952
beta 13 (t*lnL)	-0.048***	0.009	-5.361
beta 14 (t*lnS)	0.063***	0.013	4.803
Technical Inefficiency Equation			
delta 1 (TRD)	-4.146**	2.355	-1.761
delta 2 (H)	0.004***	0.001	3.060
delta 3 (P*TRD)	-0.010*	0.007	-1.549
delta 4 (M*TRD)	0.005***	0.002	2.679
delta 5 (H*TRD)	0.003*	0.002	1.516
delta 6 (P*FDI)	0.055***	0.011	5.195
delta 7 (H*FDI)	-0.050***	0.004	-11.536
delta 8 (P*M)	0.44E-05***	0.1E-05	3.892
delta 9 (M*H)	-0.41E-05*	0.3E-05	-1.596
Sigma-squared	0.209***	0.022	9.410
gamma	0.690***	0.041	16.652

Notes: ***,** and * significance at 1%, 5% and 10%.

The elasticity of substitution for each province in China has been computed when using the estimated parameters of frontier production function according to the corresponding calculation formulas in the foregoing methodology. Take RGDP series as dependent variable and the others as explanatory variables, CE and its ECM has been regressed and displayed in Table 2. Although the parameter of σ_{KL} is not statistically significant, it is still retained in cointegrating model in order to highlight the impacts of different types of substitution elasticity on economic growth.

Table 2 Regression Results Of Ce and Ecm.

Cointegrated Equation				Error Correction Model			
Dependent Variable: RGDP? Method: Pooled Least Squares Cross-sections included: 29 Total pool (balanced) observations: 551				Dependent Variable: D(RGDP?) Method: Pooled Least Squares Cross-sections included: 29 Total pool (balanced) observations: 522			
Variable	Coefficient	Std. Error	t	Variable	Coefficient	Std. Error	t
C	-1.826***	0.143	-7.528	C	-0.003	0.013	-0.206
σ_{KL}?	8.37E-07	1.30E-05	0.064	D (σ_{KL}?)	7.04E-07	7.86E-06	0.090
σ_{KS}?	0.374***	0.067	5.585	D (σ_{KS}?)	0.801***	0.075	10.631
σ_{LS}?	0.064*	0.038	1.671	D (σ_{LS}?)	0.088*	0.047	1.876
PMH?	0.001***	0.000	4.368	D (PMH?)	0.003***	0.000	7.299
TE?	1.823***	0.179	10.194	D (TE?)	3.525***	0.158	22.249
TRD?	-0.273***	0.090	-3.038	D (TRD?)	-0.456***	0.130	-3.501
RGDP?(-1)	-0.369***	0.040	-9.240	D(RGDP?(-1))	-0.191***	0.029	-6.564
KLS?	-0.003*	0.002	-1.673	D (KLS?)	-0.014***	0.003	-4.597
				RESID?(-1)	-1.182***	0.052	-22.896
Effects Specification Cross-section fixed (dummy variables)				Effects Specification Cross-section fixed (dummy variables)			
R-squared	0.232	AdR	0.178	R-squared	0.781	Ad R	0.764
F-statistic	4.304D-W	1.995	F-statistic	46.559	D-W	2.088	

3.3 Discussion

The elasticity-growth nested in CE displays that σ_{KS} has a more large positively impact (0.374) with 1% statistical significance only less than that of technological efficiency (1.823) on the economic growth rate, followed by that of σ_{LS} (0.064) with 10% statistical significance, while the positive effect of σ_{KL} is weak (8.37E-07) and insignificant. Among them, the complementary phenomenon between capital input and skilled labor is more inclined to support “capital-skill complementarity hypothesis” proposed by Griliches(1969), and specifically has been confirmed by the study of Ma & Xu(2016) where they find China’s physical capital is more complementary with “mid-grade” human capital-the labor who have junior and senior high school education level-than other human capital. So this paper has come to a more specific and meaningful conclusion than the de La Grandville hypothesis, that is, in China case, it is the complementarity of capital-skilled labor and the substitutability of unskilled-skilled labor rather than the capital-labor substitution suggested by de La Grandville (1989) that play the role of engine in economic growth.

Once combining the long-term CE with its short-term ECM, the elasticity-growth of China case is further convinced that it is indeed the complementarity of capital-skilled labor and the substitutability of unskilled-skilled labor, rather than the substitution of capital-labor of the de La Grandville hypothesis, that have developed into an engine of China’s sustainable economic growth. As shown in Table 2, regardless of the long-term or short-term parameters, σ_{KS} , σ_{LS} and σ_{KL} are positively correlated with economic growth, especially σ_{KS} has a far greater impact on economic growth than σ_{LS} , and both of them are significantly greater than σ_{KL} . So far, the central conclusion on elasticity-growth nexus has been reached that the capital-skill complementarity and unskilled-skill substitutability support the sustainable growth of China’s economy. Undoubtedly these findings have an important guiding significance on the efforts to promote and achieve satisfactory sustainable growth in China.

4. Conclusion

Although there are more and more theoretical advances on the role of in economic growth, empirical studies are scant; rare is it in exploring the elasticity-growth nexus by estimating time-varying substitution elasticity. Especially it is even rarer, from the perspective of the abundant factor's heterogeneity, to reveal the impact of the evolution of multi-factor elasticities of substitution on economic growth. Different from the de La Grandville hypothesis, this paper in China case strong supports for the capital-skill complementarity hypothesis, which exhibits that it is the complementarity between capital and skilled-labor and the substitutability between unskilled- and skilled-labor, rather than the capital-labor substitution, that develop into an engine of China's sustainable economic growth whether in the long-run CE or in the short-run ECM.

Research findings in this paper have theoretical and empirical implications. First, the theoretical study on σ needs to be further deepened and refined. Economic growth is a process of multi-factor inputs combined production, all information concerning the nature of production technology should be incorporated in production functions and further embedded in elasticities of substitution. So future researches should not be confined simply to investigate capital-labor substitution, but pay more attention to factors' heterogeneity, especially the heterogeneity of abundant factors. Second, this paper not only provides new ideas for theoretical research but also enriches and expands empirical research on elasticity-growth relationship from a multi-factor perspective and estimate methods. To the best of my knowledge, this paper is the first to use time-varying elasticity of substitution to explore the dynamic elasticity-growth nexus, and deeply portray the evolving elasticity of substitution in China's great expansion.

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