DRIVERS OF TOTAL FACTOR PRODUCTIVITY: EVIDENCE FROM THE GREAT SILK ROAD REGION

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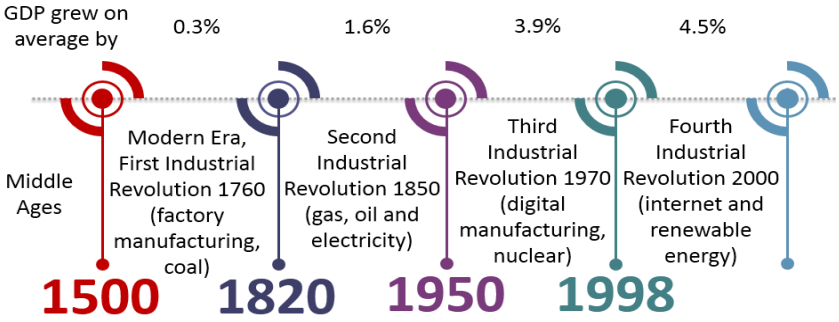
Abstract. *The study examines how health, human capital, exports, imports, and energy influence total factor productivity (TFP) using panel data from 86 countries in the historical Great Silk Road region, covering the years 1991 to 2019. The analysis is conducted in two phases: first, TFP is estimated through a regression of the Cobb-Douglas function; second, the factors affecting TFP are analyzed, emphasizing health and human capital. The results indicate that health, human capital and exports significantly enhance TFP, while imports and energy consumption have a significant negative impact on TFP.*

Keywords: *TFP, growth theory, growth accounting, Pooled OLS, Fixed Effects, Random Effects*

Introduction

The theory of economic growth has always been crucial to comprehending and characterizing economic processes. Economic historian Angus Maddison (2001) asserts that for the past 50 years, the global economy has done better than at any other time. With an average annual growth rate of 3.9%, the global GDP increased sixfold between 1950 and 1998. This was in contrast to 1.6% between 1820 and 1950 and only 0.3% between 1500 and 1820. Furthermore, the world GDP doubled between 1998 and 2019, averaging a growth rate of 4.5% per year, according to data from the Penn World Table 10.0.



It is noteworthy that Maddison purposefully chose the years 1500, 1820, and 1950: 1500 denotes the end of the Middle Ages and the start of the Modern Era, 1820 the end of the First Industrial Revolution (factory manufacturing), and 1950 the beginning of the Third Industrial Revolution (digital manufacturing). In addition, Maddison noted that since 1820, the world's development has become much more dynamic, resulting in a population rise of more than five times and an increase in per capita income of more than eight times. This growth hasn't been consistent, though, throughout time and space. Australia, Japan, North America, and Western Europe all had noticeably larger rises in income. In 1820, the income ratio between this group of nations and the rest of the globe was 2:1; by 1998, it was 7:1, and the gap is still widening.

According to Prescott (1998), differences in the timing and rate of TFP expansion are the cause of the notable income gaps between nations and regions. Because continuous development in total factor productivity started in the West around 1800, more than a century before it did in China, people in Western Europe were, on average, 12 times wealthier than people in China by 1950.

The ratio of total output (like GDP) to total inputs is known as TFP. This connection is often represented using the Cobb-Douglas production function: $Y = A \cdot K^{\alpha} \cdot L^{\beta}$, where Y is output, A is TFP, K is capital, L is labor, and α and β are the proportions of contribution for labor and capital, respectively. The amount of output growth that cannot be ascribed to increases in labor and capital is known as TFP growth. The latter has a larger TFP, showing better technological improvement, if, for example, one country uses 20 workers and 50 units of capital to manufacture 100 units, while another produces 200 units with the same resources. In a similar vein, a nation's TFP increases by 3% if its output grows by 6% and its labor and capital increase by 1% and 2%, respectively. This demonstrates that productivity involves more than just working harder; it also involves working smarter.

The Silk Road, a significant historical trade route, thrived from the second century B.C. until the fourteenth century A.D., linking the East and West, including regions such as China, India, Persia, Arabia, Greece, and Italy. Coined by German geologist Baron Ferdinand von Richthofen, the term "Silk Road" reflects the primary trade item of silk from China. However, the route facilitated the exchange of numerous vital goods, including gunpowder, paper, tea, medicine, porcelain, spices, dyes, perfumes, rice, textiles, and more.

In 2013, China launched the Belt and Road Initiative, aiming to revive this ancient trade network by investing in over 150 nations and global institutions. By 2019, the 86 countries within the Great Silk Road (GSR) region accounted for over 76% of the global population and more than 68% of the world's real GDP, with 36 of the top 50 economies situated in this region. The countries involved range from Albania to Yemen, encompassing diverse cultures and economies:

Albania, Algeria, Armenia, Austria, Azerbaijan, Bangladesh, Bahrain, Belarus, Belgium, Bhutan, Bosnia and Herzegovina, Brunei Darussalam, Bulgaria, Cambodia, China, Croatia, Czech Republic, Denmark, Djibouti, Egypt, Estonia, Ethiopia, France, Georgia, Germany, Greece, Hungary, India, Indonesia, Iran, Iraq, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Latvia, Lebanon, Lithuania, Luxembourg, Madagascar, Malaysia, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Nepal, Netherlands, North Macedonia, Oman, Pakistan, Philippines, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Saudi Arabia, Serbia, Singapore, Slovakia, Slovenia, Spain, Sri Lanka, Sudan, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, United Republic of Tanzania (Mainland), United Arab Emirates, United Kingdom, Uzbekistan, Viet Nam, and Yemen.

Given this rich historical and economic context, the objective of this research is to estimate TFP and its determinants for these countries. To understand the complexities of TFP in the GSR region, it is essential to examine existing literature on productivity measurements, the influence of economic factors, and the role of technological advancements in shaping these economies.

Literature review

TFP estimation. Hulten (2000) offers a thorough overview of the evolution of the total factor productivity (TFP) concept, highlighting that Robert Solow (1957) was the first to link the

aggregate production function to productivity. Solow's growth model examines the total differential of the production function, represented as:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha \cdot \frac{\Delta K}{K} + \beta \cdot \frac{\Delta L}{L}$$

This model employs growth accounting (or index) methods to measure TFP growth based on observed values of other variables. Specifically, Solow analyzed the aggregate output function of the U.S. from 1909 to 1949, concluding that one-eighth of the total increase in output was due to increased capital per man-hour, while the remaining seven-eighths could be attributed to technical change.

Hulten also notes that Denny, Fuss, and Waverman (1981) were pioneers in applying growth regression to estimate the parameters α and β through regression analysis. Since then, a substantial body of literature has emerged focusing on TFP estimation. For instance, Felipe (1997) reviewed empirical studies on total factor productivity and growth sources in East Asian countries. Yormirzoev (2022) examined the long-term economic performance of Central Asian nations, while Kutlar, Kabasakal, and Gulmez (2017) discussed efficiency, productivity, and the convergence phenomenon in 34 OECD countries from 2000 to 2012.

TFP determinants. Isaksson (2007) offers an in-depth analysis of the factors affecting TFP, highlighting influences such as human capital (represented by education and health), infrastructure, institutional frameworks, openness to trade, research and development, foreign direct investment, financial development, and geographical factors.

Alvi and Ahmed (2014) examined the impact of health and education on TFP by utilizing panel data from 37 developed and developing countries over the period from 1990 to 2010. Their two-stage model demonstrated that both health and education have a positive effect on TFP.

Komare (2018) analyzed the factors driving TFP growth in eight European countries, emphasizing trade openness, R&D, FDI, education, and institutional frameworks. The study revealed that trade openness and education made significant contributions to TFP growth, whereas the effects of FDI and R&D were not statistically significant.

Peng, Chen, Xu, and Lee (2020) investigated the trends and determinants of green total factor productivity (GTFP) in 65 countries along the Silk Roads from 2008 to 2018. Their main findings included:

1) a general increase in GTFP levels among Belt and Road (B&R) countries

2) regional disparities in GTFP, with Western Asia and Central and Eastern Europe showing higher efficiency compared to Southeast and Central Asia

3) most countries improved GTFP efficiency, with few declines

4) significant factors influencing GTFP growth in B&R countries, such as imports, exports, industrial structure, and urbanization.

Malik, Masood, and Sheikh (2021) examined the determinants of TFP in India from 1980 to 2016 by employing a two-stage approach. They estimated TFP using growth accounting and analyzed its determinants with an Autoregressive Distributed Lag (ARDL) model. Their results showed that inflation and financial development positively influence TFP, while FDI, imports, and capital formation had positive but insignificant effects. In contrast, exports, government size, and natural disasters were found to negatively influence TFP.

Although current studies have concentrated on particular regions or countries, there is a notable absence of comprehensive longitudinal research that investigates TFP determinants across

a wider spectrum of both developing and developed nations at the same time. The literature review points out the different methodologies employed in TFP estimation; however, there is no clear agreement on the most effective methods. Our research seeks to fill these gaps in the existing literature.

Data and Methodology

We will follow the two-stage model suggested by Alvi and Ahmed (2014) and Malik, Masood and Sheikh (2021) and consider the Cobb-Douglas production function:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \qquad (1)$$

where Y is aggregate output (real GDP), K is capital input (capital stock), L is labor input (number of employed people) and A is technological progress (or total factor productivity), i is a country index, t is a time index, α is the output elasticity of capital, β is the output elasticity of labor.

Stage 1. We take natural logarithm of (1):

$$\ln Y_{it} = \ln A_{it} + \alpha \ln K_{it} + \beta \ln L_{it} \qquad (2)$$

where $Y, K,$ and L are observable and A is unobservable (for the regression model, we consider $\ln A_{it} = u_i + \epsilon_{it}$). The parameters α and β are estimated, and TFP is calculated using the formula:

$$TFP_{it} = A_{it} = Y_{it}/(K_{it}^{\alpha}L_{it}^{\beta}) \qquad (3)$$

Stage 2. We will consider the model:

$$TFP_{it} = \eta_i + \delta_t + \beta_1 H_{it} + \beta_2 HC_{it} + \beta_3 Ex_{it} + \beta_4 Im_{it} + \beta_5 En_{it} + \epsilon_{it} \quad (4)$$

where H represents health (with life expectancy used as a proxy), HC is the human capital index (based on years of schooling and returns to education), Ex denotes exports (as a percentage of GDP), Im denotes imports (as a percentage of GDP), En represents fossil fuel (coal, oil, gas, etc.) energy consumption (as a percentage of total consumption).

The data for real GDP (rgdpna), capital stock (rnna), labor force (emp) and human capital index (hc) are obtained from the Penn World Table 10.0 (Feenstra et. al., 2015), while data on exports, imports and energy are sourced from the World Bank (WDI).

Results and Discussions

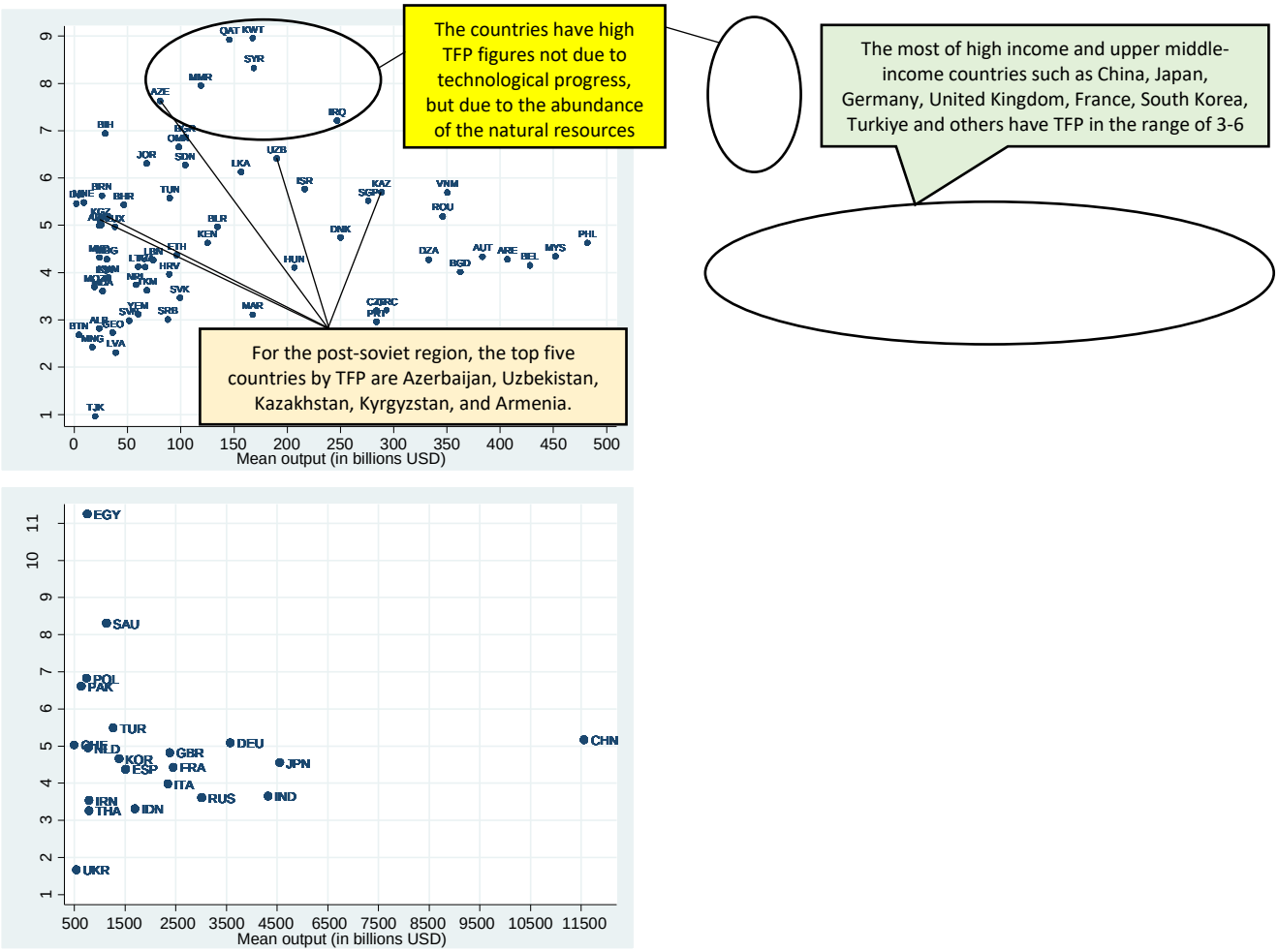
Stage 1. The estimates of the econometric model (2) are presented below:

Dependent: GDP	**Pooled OLS**	**Random Effects**	**Fixed Effects**
$Capital\ (\alpha)$	0.7130^{***} (0.0062)	0.7536^{***} (0.0118)	0.7621^{***} (0.0131)
$Labor\ (\beta)$	0.2759^{***} (0.0070)	0.2367^{***} (0.0194)	0.2223^{***} (0.0239)
R^2	0.94	0.94	0.94
p-value (F-test)	0.000	0.000	0.000
n	2494	2494	2494
Note: $*\ p < 10\%,\ **\ p < 5\%,\ ***\ p < 1\%$. Standard errors in parentheses.			

The econometric analysis indicates conflicting preferences between model types. The Breusch and Pagan test, with a significant p-value of 0.000, suggests that either the Fixed Effects or Random Effects model is more appropriate than Pooled OLS, as both can account for unobserved individual effects. However, the Hausman test, which yields a p-value of 0.2973, indicates no significant preference for the RE model over the FE model. This suggests that while both the FE and RE models are suitable options, the data may align more closely with the assumptions of the RE model, making it the preferred choice for this analysis.

Thus, the TFP values are calculated using the formula: $P_{it} = \frac{Y_{it}}{K_{it}^{0.7536} L_{it}^{0.2367}}$.

The figure below displays the mean values of TFP and output (real GDP) for the 86 countries over the time span of 1991 to 2019.



Countries like Qatar, Kuwait, Iraq, Saudi Arabia, Azerbaijan, and Oman exhibit high TFP values primarily due to their rich natural resources rather than technological advancements. Most high-income and upper middle-income nations, such as China, Japan, Germany, the United Kingdom, France, South Korea, and Turkey, have TFP values ranging from 3 to 6, while many lower middle and low-income countries display TFP values within a broader range of 3 to 7. This discrepancy can be attributed to the catch-up effect, where countries adopt technologies from more developed economies and experience accelerated growth. In the post-Soviet region, the top five countries by TFP are Azerbaijan, Uzbekistan, Kazakhstan, Kyrgyzstan, and Armenia.

Stage 2. The correlation matrix of the variables in model (3) is presented below:

	TFP	**Human capital**	**Health**	**Export**	**Import**	**Energy**	**VIF**
TFP	1						
Human capital	-0.11	1					2.00
Health (life exp.)	0.09	0.73	1				2.54
Export	0.06	0.34	0.34	1			5.96
Import	-0.09	0.31	0.21	0.86	1		5.60
Energy	0.19	0.37	0.54	0.24	0.10	1	1.49

Note: VIF: < 5 low correlation, 5-10 moderate correlation, >10 high correlation.

Note that the explanatory variables are not highly correlated, indicating no issues with multicollinearity. Additionally, while there are moderate correlations between export/import and health/human capital, as indicated by the variance inflation factor (VIF), it is important to recognize that correlation values and estimated parameters may differ. For instance, although TFP is negatively correlated with human capital, the estimate will be positive, as shown below. The estimates of the econometric model (3) are presented below.

Dependent: TFP	**Pooled OLS**	**Random Effects**	**Fixed Effects**
Health (life expectancy)	0.045^{***} (0.009)	0.064^{***} (0.01)	0.058^{***} (0.01)
Human capital	-0.966^{***} (0.094)	0.189^{***} (0.139)	0.379^{***} (0.147)
Export	0.029^{***} (0.004)	0.017^{***} (0.002)	0.016^{***} (0.002)
Import	-0.034^{***} (0.004)	-0.013^{***} (0.002)	-0.012^{***} (0.002)
Energy (fossil fuel consumption)	0.014^{***} (0.002)	-0.006^{***} (0.003)	-0.008^{***} (0.04)
Constant	3.224^{***} (0.534)	-0.007 (0.581)	0.0006 (0.571)
R^2	0.18	0.14	0.14
p-value (F-test)	0.000	0.000	0.000
n	1581	1581	1581
Note: $*\ p < 10\%,\ **\ p < 5\%,\ ***\ p < 1\%$. Standard errors in parentheses.			

The results of the econometric analysis indicate that the Breusch and Pagan test, with a p-value of 0.000, significantly rejects the null hypothesis (H0: Pooled OLS is better). This suggests that the Fixed Effects or Random Effects models are more appropriate for the dataset, as they account for unobserved individual effects that could bias the results. Furthermore, the Hausman test reinforces this finding with a p-value of 0.0048, leading to the rejection of the null hypothesis (H0: RE is better). This indicates a preference for the FE model, which suggests that the individual-specific effects are correlated with the explanatory variables.

Thus, the estimated model is

$$TFP_{it} = 0.0006 + 0.058H_{it} + 0.379HC_{it} + 0.016Ex_{it} - 0.012Im_{it} - 0.008En_{it}$$

Ceteris paribus, a 1-unit increase in health, human capital and exports results in increases of 0.058, 0.379 and 0.016 units in TFP, respectively. Ceteris paribus, a 1-unit increase in imports and energy consumption leads to a decrease of 0.012 and 0.008 units in TFP, respectively.

Conclusion

The TFP and its determinants for 86 countries along the Great Silk Road region are analyzed using a two-stage econometric model. In the first stage, the TFP values are estimated using three models: Pooled OLS, Random Effects, and Fixed Effects. The results of the tests suggest that the Random Effects model is the most appropriate for this stage. In the second stage, the determinants of TFP are also estimated using the same three models, and the tests indicate the Fixed Effects model is the best fit for this analysis. The preference for the Random Effects model in the first stage suggests that the unobserved individual effects are uncorrelated with the explanatory variables, which is appropriate for estimating TFP. Conversely, the choice of the Fixed Effects model in the second stage indicates that the unobserved factors influencing TFP are correlated with the determinants being analyzed, making Fixed Effects the better option for controlling these influences and providing more reliable estimates.

The findings from the analysis underscore the critical importance of strategic investments and policy reforms to enhance TFP in the Great Silk Road region. To foster sustainable economic growth and development, the following policy recommendations are proposed:

Investing in Public Health: Improving public health systems not only enhances the overall well-being of the population but also increases productivity. Healthy individuals are more capable of contributing effectively to the workforce, leading to better economic outcomes. Investments in healthcare infrastructure, preventative care, and health education can reduce disease burdens and associated healthcare costs, thus boosting productivity in the long term.

Enhancing Human Capital: Focusing on education and training is essential for developing a skilled workforce. Policies should aim to improve access to quality education, vocational training, and lifelong learning opportunities. By equipping individuals with relevant skills and knowledge, countries can foster innovation and adaptability, which are vital for competing in a rapidly changing global economy. Additionally, promoting R&D initiatives can stimulate technological advancements that further enhance productivity.

Increasing Exports: Strengthening export capacities is crucial for economic growth. Governments should implement strategies to diversify export markets and enhance the competitiveness of local products. This can be achieved through trade agreements, improving infrastructure, and supporting local industries in meeting international standards. By boosting exports, countries can increase their foreign exchange earnings and stimulate domestic economic activity.

Reducing dependence on Imports: Policymakers should develop strategies to decrease reliance on imports, particularly for essential goods and services. This could involve promoting local production through incentives for domestic industries, investing in local supply chains, and encouraging entrepreneurship. By reducing dependency on imports, countries can enhance their economic resilience and create jobs, contributing to a more self-sufficient economy.

Managing Energy Consumption: Given the negative correlation between energy consumption and TFP, it is vital to transition towards more sustainable energy sources. Implementing energy efficiency programs and investing in renewable energy technologies can help reduce fossil fuel consumption while ensuring a stable energy supply. This shift not only mitigates environmental impacts but also decreases vulnerability to energy price fluctuations, enhancing long-term economic stability.

The disparities in TFP values between developed and developing countries underscore the differing levels of technological advancement and innovation capabilities. These differences not only reflect the existing gaps in economic performance but also highlight the importance of fostering environments that encourage technological growth and development in lower-income nations. To bridge these gaps, it is essential for countries to strengthen their economic, political, and social relationships. This can be achieved through various initiatives, such as forming strategic partnerships, engaging in trade agreements, and participating in international forums focused on technology transfer and innovation. By doing so, developing countries can gain access to advanced technologies, best practices, and expertise that have been successfully implemented in more developed economies. Moreover, enhancing collaboration in R&D can lead to joint ventures and projects that benefit all parties involved. Investing in training and education programs that promote skill development in emerging technologies is also crucial. Such efforts will not only improve local capabilities but will also foster a culture of innovation and entrepreneurship.

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