Mallick, Sushanta and Matousek, Roman and Tzeremes, Nickolaos G. (2016) *Financial development and productive inefficiency: A robust conditional directional distance function approach.* Economics Letters, ISSN 0165-1765. (In press) (doi:10.1016/j.econlet.2016.06.019)

Abstract

This paper examines whether the level of financial development helps lower countries' inefficiency using time-dependent robust conditional directional distance functions in a sample of 91 countries over 1970-2011. The overall results reveal that the effect of financial development on countries' productive inefficiency is highly nonlinear, and depends on countries' income levels, suggesting that higher levels of financial development are enhancing more countries' catching-up ability rather than their technological change.

Keywords: Financial development; Technological change; Technological catch-up; Productive inefficiencies; Robust directional distance functions.

JEL classifications: C14; C61; G10; O30; O47

1. Introduction

The relationship between financial development and economic growth has been well analysed in the literature for several decades (King and Levine, 1993). Goldsmith (1969) was the first study suggesting that this relationship can be bidirectional. However, several studies suggest that money causes output (Berger and Österholm, 2009; Shen 2013; Beck et al., 2014). Maskus et al. (2012) explain the mechanism between financial development, innovation and economic growth relationship. Badunenko and Romero-Ávila (2013) provide a direct link between financial development and countries' aggregate levels of production efficiency. In their study, by applying the methodological framework of Kumar and Russell (2002), they construct a world production frontier for 57 countries over the period 1965-2005. Based on the theoretical framework of Badunenko and Romero-Ávila (2013), and the hypothesis that financial development drives growth, our study for the first time applies time-dependent conditional robust directional distance functions (Daraio and Simar, 2014; Mastromarco and Simar, 2015) to explore the effect of financial development on countries' productive inefficiency levels.

We apply robust (*order-α*) quantile directional distance functions conditioned on time and financial development for a sample of 91 countries over the period 1970-2011. We examine potential nonlinear relationships by decomposing the effect of financial development on countries' technological change (shift of the frontier) and on countries' technological catch-up. As has been highlighted by Ang (2011) even though there is empirical evidence that financial development contributes to countries' economic growth, there is lack of empirical studies investigating the financial development – technological deepening relationship. To this end our paper contributes to the existing literature by filling this empirical gap incorporating the latest advances on robust nonparametric frontiers and providing empirical evidence on the effect of financial development on countries' technological catch-up and technological change levels.

2. Methodology

Let us consider countries' production process as a set of p inputs and q outputs. Then the production set of the technical feasible combinations can be represented as:

$$\Psi = \left\{ (x, y) \in \Re_{+}^{p+q} \middle| \text{x can produce y} \right\}. \tag{1}$$

Then the Farrell output distance of (x, y) can be obtained as:

$$\lambda(x, y) = \sup\left\{ \lambda > 0 \middle| (x, \lambda y) \in \Psi \right\}. \tag{2}$$

By following Daraio and Simar (2014), we consider the joint probability measure of (X, Y) and the probability function $H_{XY}(.,.)$ defined as:

$$H_{XY}(x, y) = \text{Prob}(X \leq x, Y \geq y), \tag{3}$$

then Ψ can be identified with the support of $H_{XY}(.,.)$ as:

$$\Psi = \left\{ (x, y) \in \Re^{p+q} \middle| H_{XY}(x, y) > 0 \right\}. \tag{4}$$

Furthermore, as it has been described in the related literature (Bădin et al. 2012; Daraio and Simar, 2014; Mastromarco and Simar, 2015) and in the presence of time and financial development, we can further define the probabilistic formulation for countries' production process introduced previously. Specifically, let $Z \in \Re^{d}$ denote the vector of factors/variables which is influencing the production process.[1] Furthermore, the time T as an additional conditional variable for each time period t defines the attainable set $\Psi_t^z \subset \Re_{+}^{p+q}$ as the support of the conditional probability:

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[1] In our case, it is countries' M2 levels as a percentage of their GDP.

$$H^{t}_{X,Y|Z}\left(x,y\middle|z\right)=\text{Prob}\left(X\le x,Y\ge y\middle|Z=z,T=t\right). \quad (5)$$

Then by following Daouia and Simar (2007) for any $\alpha\in(0,1]$ with

$F_X\left(x\right)=\text{Prob}\left(X\le x\right)>0$ the order-α quantile estimation can be obtained as:

$$\lambda_\alpha\left(x,y\right)=\sup\left\{\lambda>0\middle|S_{Y|X}\left(x,\lambda y\right)>1-\alpha\right\}, \quad (6)$$

where $S_{Y|X}\left(x,y\right)=\text{Prob}\left(Y\ge y\middle|X\le x\right)$.[2]

Recently Simar and Vanhems (2012) have introduced the probabilistic version of directional distance functions and the link with the order-α distances. In a general framework, consider a positive directional distance vector $g=\left(g_x,g_y\right)\in\Re_+^{p+q}$ having the same unit as the input and output vectors[3]. Then the order-α output oriented distance function can be defined as:

$$D_\alpha\left(x,y;g_y\right)=\sup\left\{\beta\middle|S_{Y|X}\left(x,y+\beta g_y\right)>1-\alpha\right\}. \quad (7)$$

The order-α directional distance function can also be written as:

$$D_\alpha\left(x,y;g_y\right)=\log\left(\lambda_\alpha\left(\tilde{x},\tilde{y}\right)\right), \quad (8)$$

where $\lambda_\alpha\left(\tilde{x},\tilde{y}\right)=\sup\left\{\lambda>0\middle|S_{\tilde{Y}|\tilde{X}}\left(\lambda\tilde{y}\middle|\tilde{x}\right)>1-\alpha\right\}$, which is the order-α quantile estimator but in the $\tilde{x},\tilde{y}$ coordinates.[4] Then the time dependent conditional order-α directional distance function can be obtained as:

$$D_{t,\alpha}\left(x,y;g_y\middle|z\right)=\log\left(\lambda_{t,\alpha}\left(\tilde{x},\tilde{y}\middle|z\right)\right), \quad (9)$$

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[2] It must be noted that when $a\to1$ then $\lambda_\alpha\left(x,y\right)\to\lambda\left(x,y\right)$.

[3] For our case since we use output oriented measures, the directional distance vector will take the form of $g=\left(0,g_y\right)$.

[4] In order to obtain the output orientation we adapt a monotonic increasing transformation of the inputs/outputs as: $\tilde{x}=\exp\left(x\right),\tilde{y}=\exp(y./g_y)$.

where $\lambda_{t,\alpha}\left(\tilde{x},\tilde{y}\middle|z\right)=\sup\left\{\lambda>0\middle|S^{t}_{\tilde{Y}|\tilde{X},Z}\left(\lambda\tilde{y}\middle|\tilde{x},z\right)>1-\alpha\right\}$, which is the time dependent conditional order-α quantile estimator presented in Mastromarco and Simar (2015, p.831) but in the $\tilde{x},\tilde{y}$ coordinates. Furthermore, values of $D_{\alpha}\left(x,y;g_{y}\right)$ and $D_{t,\alpha}\left(x,y;g_{y}\middle|z\right)$ equal to 0 suggest that a country under evaluation is on the α-quantile frontier, whereas a positive value or a negative value indicates respectively that the country is below or above the quantile frontier. Then in a similar manner as in Daraio and Simar (2014, p363), we can analyze the effect of time and financial development by constructing the following differences:

$$\begin{aligned}\delta_{t,0.95}\left(x,y,z\right)&=D_{0.95}\left(x,y;g_{y}\right)-D_{t,0.95}\left(x,y;g_{y}\middle|z\right)\\ \delta_{t,0.5}\left(x,y,z\right)&=D_{0.5}\left(x,y;g_{y}\right)-D_{t,0.5}\left(x,y;g_{y}\middle|z\right).\end{aligned} \tag{10}$$

When choosing α value near unity (α=0.95) we analyze a robust version of the full frontiers levels and when we are choosing α=0.5 we can estimate the median of the distributions. In that respect when we are looking in a three dimensional picture[5] of $\hat{\delta}_{t,\alpha}\left(x,y,z\right)$ as a function of the elements of Z and T we are able to investigate the tendency of δ to increase or decrease with z and t. An increasing trend indicates a negative effect of z and t on the attainable set, whereas, a decreasing trend indicates a positive effect. Finally, as has been highlighted by Bădin et al. (2012) and Mastromarco and Simar (2015) when investigating the differences of $\delta_{t,0.5}$ we analyse the effect of z and t on countries' catching-up levels (effects on the distribution of inefficiencies), whereas when investigating the differences of $\delta_{t,0.95}$ we investigate the effect on countries' levels of technological change (effects on the boundary/swift of the frontier).

[5] We apply a local linear estimator and for computational issues and selections of bandwidths, see Bădin et al. (2012) and Daraio and Simar (2014).

3. Empirical Findings

We use a sample of 91 countries[6] over the period 1970-2011. We consider here the simplest production model by using countries' aggregate capital stock, total labour force and GDP.[7] Following King and Levine (1993) and Arestis and Demetriades (1997), we use money and quasi money (M2) as a proxy of financial development[8]. Specifically we deploy money and quasi money as percentage of GDP (M2), extracted from World Bank WDI database.[9] Figure 1 presents the mean inefficiencies values based on countries income classifications.[10] Subfigure 1a with the inefficiencies derived with $\alpha = 0.5$ indicates that lower- income and lower middle-income countries have increased their production inefficiencies almost in a similar manner. For the upper middle-income countries it is evident that the production inefficiencies have decreased, whereas, the lowest inefficiencies are reported for the high income countries. When we examine subfigure 1b $(a = 0.95)$ we may argue that lower income and lower middle income countries have the highest inefficiencies (above 0.9 on average terms), whereas, the upper middle income countries seem to lower their inefficiency levels. High income countries lower their production inefficiency levels in a more pronounced way compared to the other three country groups.

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[6]ARG, AUS, BDI, BEN, BFA, BHS, BOL, BRA, BRB, BWA, CAF, CAN, CHE, CHL, CIV, CMR, COD, COG, COL, CRI, DNK, DOM, ECU, EGY, FIN, FJI, GAB, GBR, GHA, GMB, GTM, HND, IDN, IND, IRL, IRN, ISL, ISR, ITA, JAM, JOR, JPN, KEN, KOR, KWT, LKA, MAR, MDG, MEX, MLI, MLT, MRT, MWI, MYS, NER, NGA, NLD, NOR, NPL, NZL, OMN, PAK, PAN, PER, PHL, PRY, QAT, ROM, RWA, SAU, SDN, SEN, SGP, SLE, SLV, SUR, SWE, SWZ, SYR, TCD, TGO, THA, TTO, TUN, TUR, UGA, URY, USA, VEN, ZAF, ZMB.

[7]The data have been extracted from Penn World Table v8.1 (Feenstra et al., 2015).

[8]Due to lack of consistent country-level data availability across different databases (PWT8.1 and WDI), we extracted our data sample for 91 countries over the period 1970-2011 for our analysis. As a robustness check we also use as a proxy of financial development the domestic credit to private sector (as % of GDP). We have compiled the variable from World Development Indicators within Datastream. Due to length restrictions the results are presented as supplemental material.

[9]The data can be downloaded from: http://data.worldbank.org/indicator/FM.LBL.MQMY.GD.ZS.

[10]For the purpose of our analysis we have chosen a direction for g_y as the maximum GDP value of every country groups.

Insert Figure 1 about here

Figure 2 presents the 3-dimensional pictures of the effect of time and financial development on countries' catch-up (subfigures 2b, 2d, 2f, 2h & 2j) and technological change (subfigures 2a, 2c, 2e, 2g & 2i) levels. The evidence of the entire sample (subfigures 2a and 2b) suggest that financial development has a positive effect on countries' technological change up to a certain level; however for higher level of M2 the effect becomes negative.[11] In fact this finding presents further evidence by supporting the studies by Shen (2013) and Beck et al. (2014) suggesting the existence of diminishing returns to improvement in financial development. Moreover, for the case of catching-up, the 3-dimensional picture suggests that countries' financial development influences positively countries' catch-up levels but in a nonlinear manner indicated by a decreasing nonparametric regression line. In both cases a nonlinear relationship is revealed providing further evidence to the studies that found that financial development-economic growth relationship is nonlinear (Shen 2013; Beck et al., 2014). For high income countries (subfigures 2c & 2d) it appears that the effect of financial development on those countries' technological change levels forms an 'N'-shape relationship, suggesting that for lower M2 levels the effect is negative, then for higher levels of M2 the effect is positive and for the top-end of M2 levels the effect becomes again negative. This means that lower productive inefficiency around the threshold level of financial development reflects more efficient allocation of financial resources while excessive financial deepening could make firms less efficient increasing the level of average inefficiency again.

On the other hand the effect of financial development on high income countries catching-up levels is positive, indicated by a decreasing nonparametric

[11]As has been explained previously, a negative slope indicates a positive effect, whereas, a positive slope indicates a negative effect.

regression line. For the upper middle income countries (subfigures 2e & 2f) the results suggest a nonlinear relationship and a positive effect of financial development both on countries' technological change and catching-up levels. For lower middle income countries (subfigures 2g & 2h) the effect suggests an inverted "U"-shape relationship both for countries' technological change and catching-up. This in turn indicates a negative effect of financial development for lower M2 values and a positive effect for higher M2 values. Moreover, for lower income countries the effect suggests a light "U"-shape relationship both for technological change and catching-up, suggesting that there is a positive effect for lower M2 but after specific threshold values of M2 the effect becomes negative both on countries' technological change and catching-up.

Insert Figure 2 about here

Finally, as a robustness check in our analysis, we re-estimate our empirical findings with domestic credit to private sector (as percentage of GDP) as a proxy for financial development instead of M2. Analogous to Figure 2, Figure 3 presents the 3-dimensional pictures of the effect of time and financial development on countries' catch-up (subfigures 3b, 3d, 3f, 3h & 3j) and technological change (subfigures 3a, 3c, 3e, 3g & 3i) levels. It appears that the new findings are aligned with the previous ones, suggesting in principle a similar tendency both for the effect on countries' technological change and technological catch-up levels. Even though, the nonlinear shapes of the 3-dimentional pictures and the turning points are in some cases different, the overall tendencies are aligned with our previous findings. An exception however can be observed for the case of lower income countries (subfigure 3i) in which the empirical findings suggest a positive effect on countries' technological change for all values of domestic credit to the private sector.

Insert Figure 3 about here

4. Conclusions

Based on the theoretical framework of Badunenko and Romero-Ávila (2013) our paper applies conditional robust directional distance frontiers analysis in order to examine the dynamic effects of financial development on countries' productive inefficiency levels. Specifically, the paper applies the recent developments on efficiency measurement (Daraio and Simar, 2014; Mastromarco and Simar, 2015) on a sample of 91 countries over the period 1970-2011. Since frontier analysis estimates the long-run equilibrium relationship, our results provide evidence that the overall long-run effect of financial development on technological change and on technological catch-up is non-linear. To this extent we contribute to the few studies that provide empirical evidence on whether financial development affects technological deepening (Ang, 2011). The overall results suggest that the effect of financial development is positive on countries' technological change and on technological catch-up but it is subject to countries' income levels. Finally our findings, regardless of the proxy of financial development whether domestic credit to private sector or M2, suggest that the relationship between financial development, technological change and technological catch-up is highly nonlinear supporting the resent studies by Shen (2013) and Beck et al. (2014) suggesting an inverted U-shaped nonlinear relationship between financial development and growth.

Acknowledgements: We would like to thank Pierre-Daniel Sarte (the Editor) and an anonymous reviewer for their constructive comments on a previous version of our manuscript. Any remaining errors are solely the authors' responsibility.

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Figure 1: Diachronical representation of countries' robust inefficiency levels based on countries' income levels

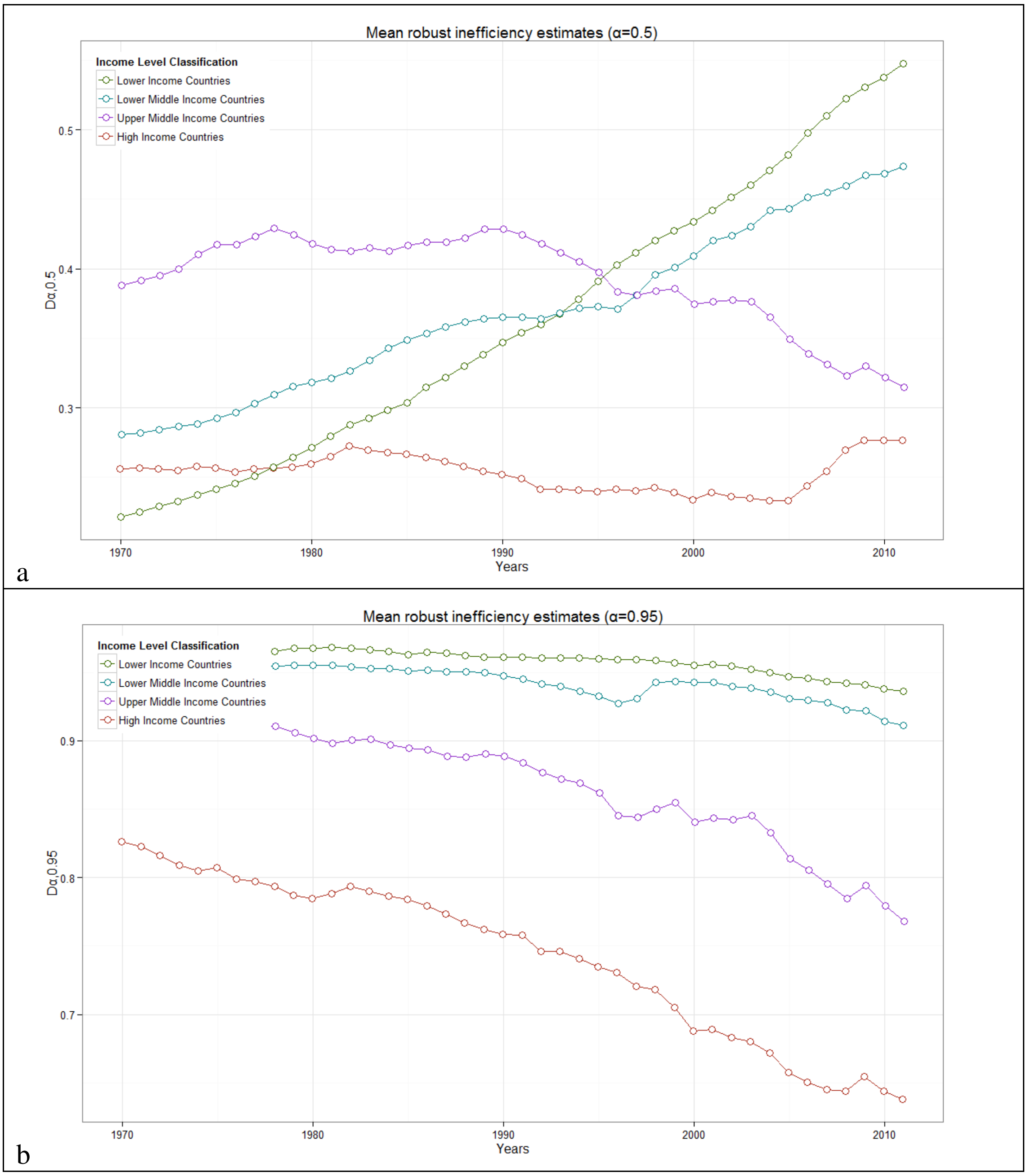
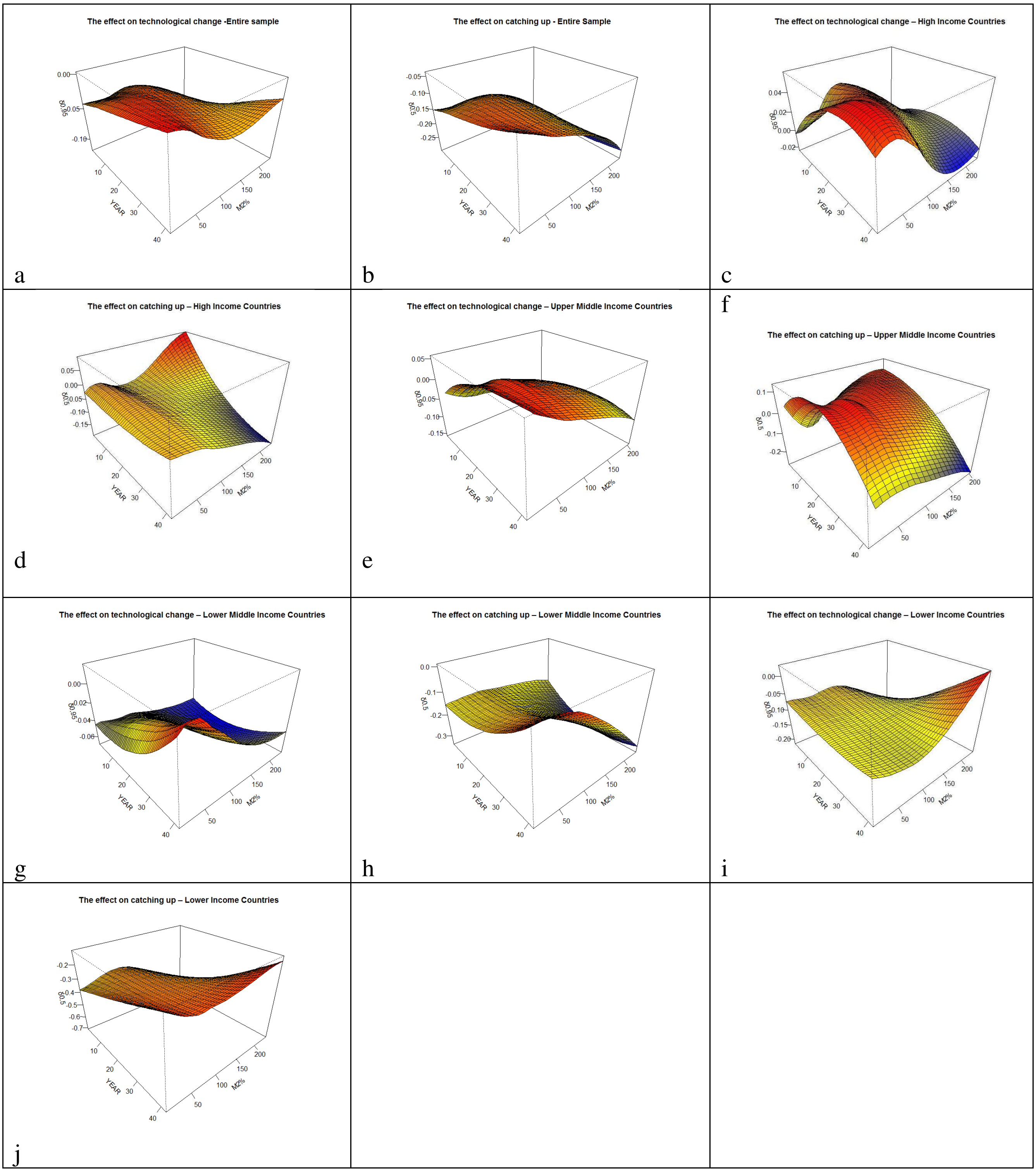
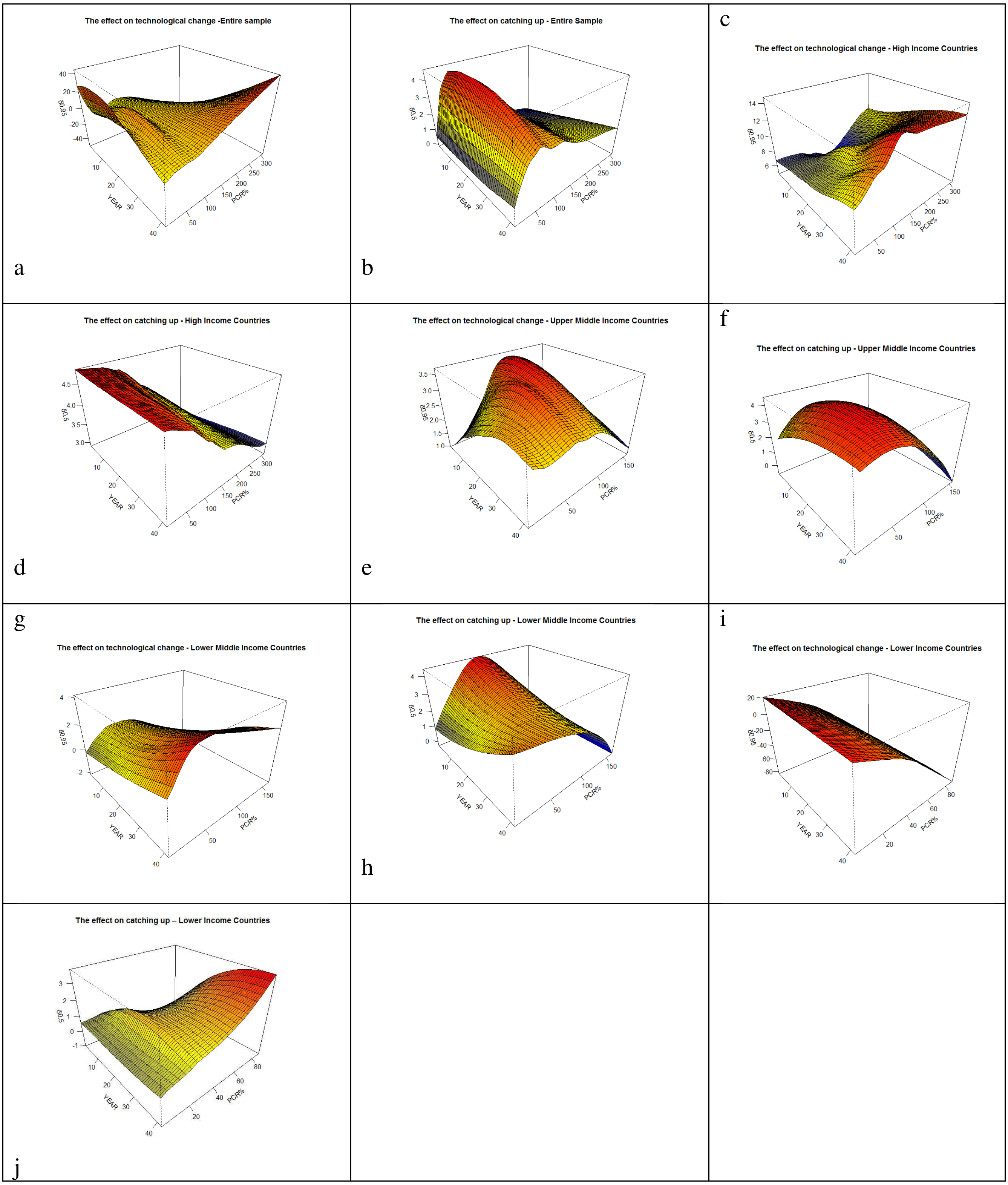


Figure 2: The effect of 'M2' and 'time' on countries' technological change and technological catch-up.



Note: In our case the predictor variables from the local linear regressions are displayed on the axes labelled as 'YEARS' and 'M2%', and the response variable (i.e. $\delta_{0.5}$, $\delta_{0.95}$) is then represented by a grid (i.e. a wireframe plot in a three-dimensional picture).

Figure 3: The effect of domestic credit to private sector (as % of GDP)-'PCR%' and 'time' on countries' technological change and technological catch-up.



Note: In our case the predictor variables from the local linear regressions are displayed on the axes labelled as 'YEARS' and 'PCR%', and the response variable (i.e. $\delta_{0.5}$, $\delta_{0.95}$) is then represented by a grid (i.e. a wireframe plot in a three-dimensional picture).