Real Money Balances and TFP Growth: Evidence from Developed and Developing Countries

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Abstract

1. Introduction

Since the pioneering work by Levhari and Patinkin (1968) and Sinai and Stokes (1972) several empirical studies have attempted to identify the role of real money balances on aggregate production function. However, this bunch of empirical work followed different tracks. Some researchers based on the initial contention made by Sinai and Stokes (1972, p. 290) that "real money balances increase the economic efficiency of a monetary compared with a barter economy" (*e.g.*, Prais, 1975; Ben-Zion and Ruttan, 1975; Short, 1979; Subrahmanyam, 1980; Khan and Ahmad, 1985; Betancourt and Robles, 1989) have argued that real money balances should be included as a separate input in the production process together with conventional inputs (*i.e.*, physical capital and labour).

However, this production-based approach has been heavily criticized by several other authors (*e.g.*, Fischer, 1974; Claassen, 1975; Davidson, 1979; Nguyen, 1986) arguing that viewing real money balances as a conventional factor of production is conceptually flawed as the technical relationships of the production process are confounded with the underlying exchange relationships that real money balances actually reflect. In an attempt to overcome this criticism recently Delorme *et al.*, (1995) and Nouzrad (2002) argued that real money balances do affect the overall productivity in the economy indirectly through their impact in the efficient utilization of the conventional inputs. Specifically, they suggest the indirect use of real money balances as a factor affecting technical efficiency rather than as a separate input in the aggregate production process.

The main objective of this paper is to enrich our knowledge on the true effect of real money balances on the production process, by providing empirical evidence of their impact on TFP changes in a sample of 79 developing and industrialized countries during the 1965-1992 period. For doing so we integrate both production-based and technical inefficiency approaches into a single framework using the notion of non-neutral stochastic production frontier proposed by Huang and Liu (1994). This general specification allows to statistically examine each of the aforementioned approaches concerning the treatment of real money balances in country's' overall productivity as a special case within the proposed formulation. That is, formal statistical testing is used to check whether real money balances should be included only in the production frontier or in the inefficiency effect model, or in both. In the latter case, an empirical evaluation of the true effects of real money balances on TFP changes can be obtained using the integrated primal approach developed by Bauer (1990), Lovell (1996) and Kumbhakar (2000).

The rest of the paper is organized as follows. Section 2 presents the theoretical framework of TFP decomposition identifying the direct and indirect effects of real money balances and the empirical specification of the model. The data used in this study and the empirical results are discussed in Section 3. Finally, Section 4 summarizes and concludes the paper.

2. Theoretical Framework

Consider that countries are using physical capital and labour $x=(K,L)$ along with real money balances (*m*) for their gross domestic aggregate production. Further, let us assume that the country's' technology can be represented through a well-behaved aggregate production frontier $f(x,m;t)$, where t proxies the state of technology at year *t*. If countries are not technical efficient then $y \leq f(x,m;t)$ and thus, output-oriented technical efficiency is defined as:

$$TE^{O}(x,m,y;t)=y/f(x,m;t) \qquad (1)$$

where $0<TE^{O}(x,m,y;t)\leq 1$. TE^{O} relates actual to best practice output in the sense that gives the maximum amount by which aggregate output can be increased and still being producible by a given input vector under the current state of technology.

After taking the natural log of both sides of (1), and totally differentiating with respect to time results in:

$$\dot{TE}^{O}(x,m,y;t)=\dot{y}-\sum_{j=1}^{k}\varepsilon_j(x,m;t)\dot{x}_j-\varepsilon_m(x,m;t)\dot{m}-T(x,m;t) \qquad (2)$$

where a dot over a function or a variable indicates a time rate of change, $\varepsilon_j(x,m;t)$ is the output elasticity of the j^{th} input (physical capital and labour), $\varepsilon_m(x,m;t)$ is the output elasticity of real money balances and, $T(x,m,t)$ is the primal rate of technical change.

Substituting the conventional *Divisia* index of total factor productivity (TFP) growth, $\dot{TFP}=\dot{y}-\sum_{j=1}^{k}s_j\,\dot{x}_j-s_m\,\dot{m}$ into (2) yields:

$$\begin{aligned}\dot{TFP}=\dot{TE}^{O}(x,m,y;t)+T(x,m;t)+\sum_{j=1}^{k}\left[\varepsilon_j(x,m;t)-s_j\right]\dot{x}_j \\ +\left[\varepsilon_m(x,m;t)-s_m\right]\dot{m}\end{aligned} \qquad (3)$$

where $s_j=(w_jx_j)/C$ and $s_m=(w_m m)/C$ are the cost shares of the j^{th} conventional input and money supply, respectively, w_j and w_m are the respective prices and C is the total cost of aggregate domestic production. Equation (3), firstly developed by Bauer (1990), attributes TFP growth to changes in technical efficiency (first term), to technical change (second term) and, to a hodgepodge of returns to scale and cost efficiency effects (third and fourth terms). Alternatively, following Kumbhakar (2000) (3) may be written as:

$$\begin{aligned}\dot{TFP}=\dot{TE}^{O}(x,m,y;t)+T(x,m;t)+(E-1)\left\{\sum_{j=1}^{k}\left[\frac{\varepsilon_j(x,m;t)}{E}\right]\dot{x}_j+\left[\frac{\varepsilon_m(x,m;t)}{E}\right]\dot{m}\right\}+ \\ +\sum_{j=1}^{k}\left[\frac{\varepsilon_j(x,m;t)}{E}-s_j\right]\dot{x}_j+\left[\frac{\varepsilon_m(x,m;t)}{E}-s_m\right]\dot{m}\end{aligned} \qquad (4)$$

where $E=\sum\varepsilon_j(x,m;t)+\varepsilon_m(x,m;t)$ is the scale elasticity that is grater, equal, or less than one under increasing, constant, or decreasing returns to scale, respectively. The last two terms in (4) capture either deviations of input prices form the value of their marginal products or departures of marginal rate of technical substitution from the ratio of input prices. However, under profit maximization and allocative efficiency $w_j = p\left[\partial f(x,m;t)/\partial x_j\right]$ and $w_m = p\left[\partial f(x,m;t)/\partial m\right]$ which imply $s_j = \varepsilon_j(x,m;t)/E$ and $s_m = \varepsilon_m(x,m;t)/E$ (Chan and Mountain, 1983). Then, (4) may be rewritten as (Lovell, 1996):

$$\begin{aligned} \dot{TFP} = \dot{TE}^O(x,m,y;t) + T(x,m;t) + (E-1)\sum_{j=1}^{k}\left[\frac{\varepsilon_j(x,m;t)}{E}\right]\dot{x}_j + \\ + (E-1)\left[\frac{\varepsilon_m(x,m;t)}{E}\right]\dot{m} \end{aligned} \tag{5}$$

where the last two term refer to the effect returns to scale may have on TFP changes. These terms vanish under constant returns to scale (*i.e.*, E=1) and thus, TFP growth is attributed to changes in technical efficiency and technical change, as in Nishimizu and Page (1982). The scale effect is, however, positive (negative) under increasing (decreasing) returns to scale as long as conventional input use and money supply increases and *vice versa*. Its relative contribution depends on both the magnitude of the scale elasticity and the rate of input quantity changes. If a flexible functional form is used to approximate aggregate production frontier it can be shown that the effect of real money balances on TFP growth goes beyond it's direct scale effect captured by the last term in (5). Specifically, real money balances affect TFP growth indirectly through all other terms in the RHS of (5).

To see empirically how this is accomplished we can assume that countrys' aggregate stochastic production frontier is approximated using a translog specification under input-biased technical change *i.e.*,

$$\begin{aligned} \ln y_{it} = \beta_0 + \sum_{j=1}^{2}\beta_j \ln x_{jit} + \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2}\beta_{jk} \ln x_{jit} \ln x_{kit} + \beta_m \ln m_{it} + \\ \frac{1}{2}\beta_{mm} \ln m_{it}^2 + \frac{1}{2}\sum_{j=1}^{2}\beta_{jm} \ln x_{jit} \ln m_{it} + \beta_T t^2 + \frac{1}{2}\beta_{TT} t^2 + \\ + \sum_{j=1}^{2}\beta_{Tj} \ln x_{jit} t + \beta_{Tm} \ln m_{it} t + e_{it} \end{aligned} \tag{6}$$

where, e_{it} is the composed error term consisting of two independent elements such that $e_{it} \equiv v_{it} - u_{it}$. The component v_{it} is a symmetric *i.i.d.* error term that represents random variation in aggregate output as well as the effects of omitted explanatory variables, measurement errors, and statistical noise. The component u_{it} is a non-negative error term representing the stochastic shortfall of countrys' aggregate output from the production frontier due to output-oriented technical inefficiency. It is further assumed that v_{it} and u_{it} are independently distributed from each other.

Following Huang and Liu's (1994) non-neutral specification of the stochastic production frontier, the technical inefficiency effects, u_{it}, in (6) can be replaced by a linear function of explanatory variables reflecting country-specific characteristics as well as of real money supply and time. The technical inefficiency effects are assumed to be independent and non-negative truncations (at zero) of the normal distribution with unknown variance and mean. Specifically,

$$u_{it} = \delta_0 + \sum_{s=1}^{S} \delta_s z_{sit} + \delta_T t + \sum_{s=1}^{S} \delta_{Ts} z_{sit} t + \delta_m \, ln\, m_{it} + + \delta_{Tm} \, ln\, m_{it} t + \omega_{it} \qquad (7)$$

where z_{sit} are country- and time-specific explanatory variables associated with technical inefficiencies, t is a simple time trend capturing intertemporal variation in technical inefficiency, δ's are parameters to be estimated, and ω_{it} is a random variable with zero mean and finite variance σ_{ω}^2 defined by the truncation of the normal distribution such that $\omega_{it} \geq -g(z,m,t;\delta)$. This implies that the means, $\mu_{it} = g(z,m,t;\delta)$, of the u_{it} are different among countries but the variance, σ_{ω}^2, is assumed to be the same.

After substituting (7) into (6) the resulting model can be estimated by a single-equation estimation procedure using the maximum likelihood technique. Following Battese and Broca (1997), the variance parameters of the likelihood function can be estimated in terms of $\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2 / \sigma^2$.[1] The ratio-parameter γ takes values between zero and one. The closer the estimated value of γ to one, the higher the probability that technical inefficiency is significant in explaining output variability among sample participants. The production-based and the inefficiency effect approaches on modeling the impact of money supply can be retrieved as special cases of the general formulation by imposing the appropriate parametric restrictions on (6) and (7).

Country-specific estimates of output-oriented technical inefficiency are obtained directly from the estimated mean and variance of u_{it} as follows (Battese and Broca, 1997):

$$TE_{it}^{O} = E\{exp(-u_{it})|e_{it}\} = exp\left(-\mu_{it}^{0} + 0.5\sigma_{o}^{2}\right)\left\{\frac{\Phi\left[\left(\mu_{it}^{0}/\sigma_{o}\right)-\sigma_{o}\right]}{\Phi\left(\mu_{it}^{0}/\sigma_{o}\right)}\right\} \qquad (8)$$

where $\mu_{it}^{0} = \frac{\sigma_{v}^{2}\mu_{it} - \sigma_{\omega}^{2}e_{it}}{\sigma_{v}^{2} + \sigma_{\omega}^{2}}$, $\sigma_{o}^{2} = \frac{\sigma_{\omega}^{2}\sigma_{v}^{2}}{\sigma_{\omega}^{2} + \sigma_{v}^{2}}$, $\Phi(\bullet)$ is the cumulative density function (*cdf*) of the standard normal random variable and, E is the expectation operator.

Based on (8), the annual rate of change in output-oriented technical efficiency may be calculated as follows:

$$\frac{\partial TE_{it}^{O}}{\partial t} = -\xi\delta_{T} - \xi\sum_{s=1}^{S}\delta_{Ts}z_{sit} - \xi\delta_{Tm}\, ln\, m_{it} \qquad (9)$$

where $\xi = 1 - \sigma_{\omega}^{-1}\left\{\frac{\varphi(\rho - \sigma_{\omega})}{\Phi(\rho - \sigma_{\omega})} - \frac{\varphi(\rho)}{\Phi(\rho)}\right\}$, $\rho = \mu_{it}/\sigma_{\omega}$ and $\phi(\bullet)$ is the probability density functions of the standard normal variable. The first term on the RHS of (9) is the impact of unobservable factors on, the second-term is the effect of the country-specific factors and, the last term measures the effect of real money balances on technical inefficiency changes through time.[2]

On the other hand, given (6), the primal rate of technical change is measured as:

$$T_{it}(x,m;t) = \beta_{T} + 0.5\beta_{TT}t + \sum_{j=1}^{2}\beta_{Tj}\, ln\, x_{jit} + \beta_{Tm}\, ln\, m_{it} \qquad (10)$$

where, the first two-terms are the pure component of technical change and, the last two terms are the non-neutral component. The second part of the non-neutral component provides the impact of money supply on the rate of technical change which also affects indirectly TFP growth.[3]

Analogously, the frontier output elasticities with respect to real money balances and conventional inputs (physical capital and labour) are obtained from the following relations:[4]

$$\varepsilon_{mit} = \beta_m + 0.5\beta_{mm}\, ln\, m_{it} + 0.5\sum_{j=1}^{2} \beta_{jm}\, ln\, x_{jit} \tag{11a}$$

and

$$\varepsilon_{jit} = \beta_j + 0.5\sum_{k=1}^{2} \beta_{jk}\, ln\, x_{kit} + 0.5\beta_{jm}\, ln\, m_{it} \tag{11b}$$

Accordingly, a primal measure of returns to scale is provided by the sum of (11a) and (11b) over j $\left(i.e., \mathrm{E}_{\mathrm{it}} = \sum_{j} e_{jit} + e_{mit} \right)$.

Finally, the indirect effect of real money balances through the scale effect of conventional inputs in (5) can be retrieved from (6) as follows:[5]

$$(E-1)\sum_{j=1}^{2} \left(\frac{\beta_{jm}\, ln\, m_{it}}{E} \right) \dot{x}_{jit} \tag{12}$$

2. Data and Empirical Results

For the quantitative assessment of the effect of real money balances on TFP growth we used an unbalanced data set of 54 developing and industrialized countries[6] covering the period from 1975 to 1990. The data on GDP at constant 1985 international prices, physical capital and labour units are obtained from *Penn World Tables (Mark 5.6)*. Data on real money balance aggregates (M2) are obtained from the *Global Development Network Growth Database* developed by the *World Bank*. As explanatory variables in the inefficiency effects model in (7) we have used countrys' openness and real exchange rate obtained from *Penn World Tables 5.6*, total domestic savings, gross domestic investments and countrys' total trade obtained from *Global Development Network Growth Database*.

Parameter estimates of the production frontier and inefficiency effects model along with their corresponding standard errors are reported in Table 1. At the point of approximation (*i.e.*, sample mean), the modified translog production frontier is well-behaved satisfying all regularity conditions, namely positive and diminishing marginal products (the first-order parameters are all between zero and one, while the bordered Hessian matrix of the first- and second-order partial derivatives is negative semi-definite).

The variance parameters, σ^2 and γ, shown in the middle part of Table 1. The true variance for the one-sided error term, σ_u^{2*},[7] computed from these estimates was found to be 0.333 and that of the statistical noise, σ_v^{2*}, 0.046. The ratio-parameter, γ, is positive and statistically significant at the 1 percent level, indicating that the technical inefficiency is likely to have an important effect in explaining GDP variability among countries in the sample.

Specifically, the computed variance-ratio, γ^*, implies that 58.55 percent of the total variability of output produced is due to technical inefficiency, whereas the remaining portion (*i.e.*, $1- \gamma^*=0.4145$) is due to measurement errors, specification biases and factors that are not incorporated in the stochastic frontier and inefficiency effects models.

Several hypotheses concerning the specification of the production frontier model in (6) and (7) are examined using the likelihood ratio test and the results are presented in Table 2.[8] First, restrictive functional forms such as the homothetic and strongly separable Cobb-Douglas specification with Hicks neutral technical change is rejected at the 5 percent level of significance using likelihood ratio test (1st hypothesis in Table 2). In addition, the hypothesis that the average response function (*i.e.*, $u_{it}=0$) adequately represents the data set is rejected regardless of whether inefficiency effects are present[9] (2nd hypothesis in Table 2) or absent (3rd hypothesis in Table 2) in the aggregate production function model. Thus, the existing degree of technical inefficiency is an important factor in explaining GDP variability among countries in the sample.

Moreover, the stochastic frontier model cannot be reduced either to the Aigner *et al.*, (1977) half-normal or to the Stevenson (1980) truncated half-normal specification as the respective null hypotheses are rejected at the 5 percent level of significance (4th and 5th hypotheses in Table 2, respectively). Finally, the hypothesis that the estimated coefficients of the country specific variables (except time and real money balances) included in the inefficiency effects model in (7) are jointly equal to zero is also rejected at the 5 percent level (6^{th} hypothesis).

Hence, real money balances together with the country-specific characteristics are having an important role in determining individual countrys' economic performance. An important question that arises, however, is the nature of the effect of real money balances on TFP growth. Statistical testing presented also in Table 2 examines this issue.

First, the hypothesis that all the parameters associated with real money balances in both the aggregate production frontier and inefficiency effects model are jointly equal to zero is rejected at the 5 percent level of significance (7^{th} hypothesis in Table 2). The LR-test statistic also rejects the hypotheses that real money balances are not affecting either directly through the aggregate production frontier (8^{th} hypothesis) or indirectly through inefficiency effects model (9^{th} hypothesis) countrys' economic performance. Thus formal statistical testing suggests that real money balances should be included in both the aggregate production frontier and inefficiency effects models if their real impact should be identified.

The hypothesis that technical inefficiency is time-invariant is rejected at the 5 per cent level of significance (10^{th} hypothesis in Table 2). This rate of change is affected by the variables included in the inefficiency effects model in (7) (11^{th} hypothesis in Table 2). On average the pattern of efficiency indicates movements towards the production frontier over time for most countries in the sample. Thus, a positive effect of technical efficiency on output growth is found. Narrowing down this finding, the hypothesis that real money balances are not affecting indirectly the intertemporal variation of technical inefficiency ratings among countries (12^{th} hypothesis in Table 2) is rejected at the 5 per cent level of significance implying that the last term in (9) is indeed present.

Technical change was found to be present (13^{th} hypothesis in Table 2) and factor augmenting (14^{th} hypothesis in Table 2). In addition, the rate of technical change seems to be affected by real money balances as the hypothesis that β_{TM}=0 is also rejected by LR-test (15^{th} hypothesis in Table 2). Hence, the last term in (10) is different from zero affecting indirectly TFP growth rate.

The hypothesis that the aggregate production technology is characterized by linear homogeneity (constant returns to scale) is rejected by the LR-test (16^{th}

hypothesis in Table 2). Thus, the scale effect is a significant source of TFP growth and it should be taken into account in (5). Finally, real money balances contribute also indirectly in this scale effect as the hypothesis that relation (12) equals to zero is rejected by LR-test (17^{th} hypothesis in Table 2).

Thus, statistical testing empirically validates the assumption made at the outset concerning the impact of real money balances on TFP growth. The results suggest that real money balances are affecting both directly and indirectly individual countrys' TFP through their effect on the marginal productivities of physical inputs and the rate of technical change as well as on the attained technical inefficiency levels.

Based on the translog parameter estimates, reported in Table 1, we computed basic features of the aggregate production structure, namely output elasticities, returns to scale and, technical change. Average values of these estimates over countries for each year of the study are presented in Table 3. Inspection of the table reveals that *ceteris paribus*, labour seems to have the largest impact on aggregate production followed by capital and real money balances. Specifically, mean point estimates were found to be 0.5758, 0.2763 and 0.2208 for labour, capital and real money balances, respectively. Returns to scale were found slightly increasing, 1.0729.

Japan exhibits the lowest point estimate of labour and capital elasticity (0.5406 and 0.0791, respectively) and Burundi and Mauritania the highest values (0.6004 and 0.4197, respectively). Regarding real money balances Indonesia and Mexico exhibit the lowest mean estimate (0.0118 and 0.288, respectively), whereas Sierra Leone and Gambia the highest (0.5109 and 0.4920, respectively).

Concerning the temporal pattern of these point estimates as it is shown in Table 3, all output elasticities follow a decreasing trend which is more in evident for money supply balances. Specifically, labour elasticity has been decreased from 0.5840 in 1965 to 0.5758 in 1992, capital elasticity from 0.2988 to 0.2545 and that of real money balances from 0.2651 to 0.1725 during the same period.

Statistical testing presented in the previous section revealed that technical change is present and factor augmented. The relevant point estimates shown in Table 3 suggest that on the average aggregate production has been increased during the 1975-90 period by 1.3376 per cent every year due to technical progress. That technical progress was initiated from the neutral component (1.9136 per cent) as the biased one was turned to negative point estimate (-0.5760 per cent).

Concerning the country-specific estimates of Japan and Canada seems to experience the highest rates of technical progress, 2.5041 per cent and 2.4412 per cent respectively. For both of these countries the biased component of technical change is positive unlike the mean value reported in Table 3 (0.5958 per cent and 0.4125 per cent, respectively). On the other hand, Sierra Leone and Gambia exhibit technical regress during the same period of 0.8576 per cent and 0.3120 per cent, respectively (in fact these are the only countries together with Paraguay that experience technical regress during the 1965-92 period).

Predicted average output-oriented technical efficiency measures for each year during the 1965-92 period are also presented in Table 3. Further, Table 4 presents the average technical efficiencies over countries and time in the form of a frequency distribution within a decile range. Mean output-oriented technical efficiency was found to be only 64.78 per cent indicating that there is a considerably scope of improvement in the use of labour, capital and real money balances for the countries in the sample. Specifically, on the average a 35.22 per cent increase of aggregate output in the countries in the sample is possible by improving their resource use without altering the use of both conventional inputs and real money balances as well as of the production technology.

However, as it is clearly gleaned from Table 3 mean output-oriented technical efficiency seems to increase through years. Specifically, from 60.61 per cent in 1965 it has been increased to 71.54 per cent at the end of the period, indicating that countries in the sample have improved their respective know how in the use of both conventional inputs and real money balances.

Concerning the inter-country distribution of mean technical efficiency estimates the results presented in Table 4 indicate a considerable divergence among countries. In particular, mean output-oriented technical efficiency over time ranges from a minimum of 30.36 per cent in Suriname to a maximum of 98.41 per cent in Australia.

The average estimates over countries of the decomposition analysis of TFP growth during the 1965-1992 period are presented in Table 5. An average annual rate over farms of 1.4481 per cent is observed for TFP growth during that period. This growth stems almost exclusively from the corresponding technical progress observed during the same period (92.4 per cent) and to a lesser extent to increases in output-oriented technical efficiency levels (7.4 per cent). The neutral component dominates the total rate of technical change as the biased component turned to negative point estimate.

The scale effect is positive as countries in the sample exhibited on the average increasing returns to scale and input use (both conventional and real money balances) increased over time. However, it's contribution in total TFP growth rate is minor (0.2 per cent) as the average point estimate of the returns to scale over farms and time were found to be close to unity.

Concerning now both the direct and indirect effect of real money balances the results presented in Table 5 reveal that they account for the 6.42 per cent of total TFP growth during the period 1965-1992. The highest contribution arises from the indirect effect through technical change (5.7 per cent) and the lowest from scale effect (0.06 per cent). Finally, the impact of real money balances through the time rate of technical efficiency is 0.101 per cent and accounts for the 0.70 per cent of the total TFP growth.

It is noteworthy the fact that real money balances contribute positively to the biased component of technical change. This means that technical progress was conventional inputs saving and real money balances using during the 1965-92 period. Concerning the other two indirect effects of real money balances they account for the 29.1 per cent of the total scale effect and only for the 9.4 per cent of the technical efficiency changes.

4. Concluding Remarks

This paper attempts to provide empirical evidence on the true impact of real money balances on aggregate countrys' productivity. By retaining both the production-based and technical inefficiency approaches as testable hypothesis within the aggregate production frontier model it was possible to disentangle their effect on TFP growth. The empirical model was based on Huang and Liu's (1994) non-neutral specification of the production frontier model while TFP decomposition analysis was based on the integrated primal approach, developed by Bauer (1990), Lovell (1996) and Kumbhakar (2000). This methodology was applied to an unbalanced panel data set of 79 developing and industrialized countries during the period 1965-1992.

First, statistical testing suggests that indeed real money balances should be included in both the production frontier and inefficiency effects models if their true impact on countrys' productivity are to be measured. The empirical results also revealed that real money balances have contributed almost by 6 per cent in total TFP growth during the 1965-92 period. The highest contribution stems for their impact through biased technical change and the lowest for the scale effect.

References

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6: 21-37.

Balk, B.M. (1998). *Industrial Price, Quantity and Productivity Indices: The Microeconomic Theory and an Application*, Dordrecht: Kluwer Academic Publishers

Battese, G.E. and S.S. Broca (1997). Functional Forms of Stochastic Frontier Production Functions and Models for Technical Inefficiency Effects: A Comparative Study for Wheat Farmers in Pakistan. *Journal of Productivity Analysis*, 8: 395-414.

Bauer, P.W. (1990). Decomposing TFP Growth in the Presence of Cost Inefficiency, Nonconstant Returns to Scale, and Technological Progress, *Journal of Productivity Analysis*, 1: 287-99.

Ben-Zion, U. and V.W. Ruttan (1975). Money in the Production: An Interpretation of Empirical Results. *Review of Economics and Statistics*, 57: 246-247.

Betancourt, R. and B. Robles (1989). Credit, Money and Production: Empirical Evidence. *Review of Economics and Statistics*, 71: 712-717.

Chan, M.W.L. and D.C. Mountain (1983). Economies of Scale and the Törnqvist Discrete Measure of Productivity, *Review of Economics and Statistics*, 65: 663-67.

Claassen, E.M. (1975). On the Indirect Productivity of Money. *Journal of Political Economy*, 83: 431-436.

Coelli, T.J. (1995). A Monte Carlo Analysis of the Stochastic Frontier Production Function. *Journal of Productivity Analysis*, 6: 247-268.

Davidson, P. (1979). Money as a Factor of production: Ultimate Neoclassical Theory or Keynesian Insight: A Rejoinder. *Journal of Post-Keynesian Economics*, 2: 280-282.

Delorme, C.D., Thompson, H.G. and R.S. Warren (1995). Money and Production: A Stochastic Frontier Approach. *Journal of Productivity Analysis*, 6: 333-342.

Fischer, S. (1974). Money and Production Function. *Economic Inquiry*, 12: 517-533.

Førsund, F.R. (1996). On the Calculation of the Scale Elasticity in DEA Models. *Journal of Productivity Analysis*, 7: 283-302.

Global Development Network Growth Database

Greene, W.H. (1999). Frontier production functions in *Handbook of applied econometrics, Volume II: Microeconomics*, M.H. Pesaran and P. Schmidt (eds), Oxford: Blackwell Publishers.

Huang, C.J. and J.T. Liu (1994). Estimation of a Non-Neutral Stochastic Frontier Production Function. *Journal of Productivity Analysis*, 5: 171-180.

Jondrow, J., C.A.K. Lovell, I.S. Materov and P. Schmidt (1982). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. *Journal of Econometrics*, 19: 233-238.

Khan, A.H. and M. Ahmad (1985). Real Money Balances in the Production Function of a Developing Country. *Review of Economics and Statistics*, 67: 336-340.

Kodde, D.A. and F.C. Palm (1986). Wald Criteria for Jointly Testing Equality and Inequality Restrictions. *Econometrica*, 54: 1243-48.

Kumbhakar, S.C. (2000). Estimation and Decomposition of Productivity Change when Production is not Efficient: A Panel Data Approach, *Econometric Reviews*, 19: 425-60.

Levhari, D. and D. Patinkin (1968). The Role of Money in a Simple Growth Model. American Economic Review, 58: 713-753.

Lovell, C.A.K. (1996). Applying Efficiency Measurement Techniques to the Measurement of Productivity Change, *Journal of Productivity Analysis*, 7: 329-40.

Nguyen, H.V. (1986). Money in the Aggregate Production Function: Re-examination and Further Evidence. *Journal of Money, Credit and Banking*, 18: 141-151.

Nishimizu, M. and J.M. Page (1982). Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965-78, *Economic Journal*, 92: 921-36.

Nouzrad, F. (2002). Real Money Balances and Production Efficiency: A Panel-Data Stochastic Production Frontier Study. *Journal of Macroeconomics*, 24: 125-134.

Prais, Z. (1975). Real Money Balances as a Variable in the Production Function: Comment. *Journal of Money, Credit and Banking*, 7: 535-543.

Short, E.D. (1979). A New Look at Real Money Balances as a Variable in the Production Function. *Journal of Money, Credit and Banking*, 11: 326-339.

Sinai, A. and H.H. Stokes (1972). Real Money Balances: An Omitted Variable from the Production Function. *Review of Economics and Statistics*, 54: 290-296.

Stevenson, R.E. (1980). Likelihood Functions for Generalized Stochastic Frontier Estimation. *Journal of Econometrics*, 13: 58-66.

Subrahmanyam, G. (1980). Real Money Balances as a Factor of Production: Some New Evidence. *Review of Economics and Statistics*, 62: 280-283.

Table 1
Parameter Estimates of the Non-Neutral Translog Stochastic Production Frontier and Inefficiency Effects Models

Parameter	Estimate	Std Error	Parameter	Estimate	Std Error
Stochastic Frontier					
β_0	0.7018	(0.0418)*			
β_L	0.5619	(0.0182)*	β_{CC}	0.0641	(0.0086)*
β_C	0.1947	(0.0318)*	β_{MM}	0.0397	(0.0101)*
β_M	0.1157	(0.0292)*	β_T	0.0219	(0.0061)*
β_{LC}	0.0007	(0.0105)	β_{TT}	-0.0027	(0.0260)
β_{LM}	-0.0102	(0.0050)**	β_{TL}	-0.0013	(0.0007)**
β_{LL}	0.0056	(0.0027)**	β_{TC}	0.0076	(0.0020)*
β_{CM}	-0.0911	(0.0170)*	β_{TM}	-0.0037	(0.0213)
σ^2	0.0441	(0.0015)*	γ	0.7955	(0.0352)*
Inefficiency Effects Model					
δ_0	0.5841	(0.0458)*	δ_{OPNT}	0.0250	(0.0253)
δ_{OPN}	-0.2138	(0.0241)*	δ_{SAVT}	0.0102	(0.0032)*
δ_{SAV}	0.0118	(0.0135)	δ_{GDIT}	-0.0503	(0.0251)**
δ_{GDI}	-0.2027	(0.0233)*	δ_{TRDT}	-0.0081	(0.0156)
δ_{TRD}	-0.0527	(0.0163)*	δ_{EXRT}	-0.0058	(0.0017)*
δ_{EXR}	0.0185	(0.0018)*	δ_{MT}	-0.0152	(0.0081)**
δ_M	-0.0385	(0.0177)**	δ_T	0.0939	(0.0472)**
$Ln(\theta)$	-274.156				

C stands for physical capital, *L* for employment, *M* for real money supply, *T* for a simple time-trend, *OPN* for countrys' openness to trade, *SAV* for total savings, *GDI* for gross domestic investments, *TRD* for total trade and, *EXR* for real exchange rate.

*(**) indicate significance at the 1 (5) percent level.

Table 2
Model Specification Tests

Hypothesis	OR-test	Critical Value (α=0.05)
1. $\beta_{LC} = \beta_{LM} = \beta_{LL} = \beta_{CM} = \beta_{CC} = \beta_{MM} = \beta_{LT} = \beta_{CT} = \beta_{MT} = 0$	54.19	$\chi_9^2 = 16.27$
2. $\gamma = \delta_0 = \delta_M = \delta_{MT} = \delta_T = 0$	30.24	$\chi_5^2 = 10.37$
3. $\gamma = \delta_0 = \delta_{OPN} = \delta_{SAV} = \delta_{GDI} = \delta_{TRD} = \delta_{EXR} = \delta_M = \delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = \delta_{MT} = \delta_T = 0$	45.87	$\chi_{15}^2 = 32.14$
4. $\delta_0 = \delta_{OPN} = \delta_{SAV} = \delta_{GDI} = \delta_{TRD} = \delta_{EXR} = \delta_M = \delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = \delta_{MT} = \delta_T = 0$	42.69	$\chi_{14}^2 = 23.69$
5. $\delta_{OPN} = \delta_{SAV} = \delta_{GDI} = \delta_{TRD} = \delta_{EXR} = \delta_M = \delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = \delta_{MT} = \delta_T = 0$	40.02	$\chi_{13}^2 = 22.36$
6. $\delta_{OPN} = \delta_{SAV} = \delta_{GDI} = \delta_{TRD} = \delta_{EXR} = \delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = 0$	35.89	$\chi_{10}^2 = 18.31$
7. $\delta_M = \delta_{MT} = \beta_M = \beta_{LM} = \beta_{CM} = \beta_{MM} = \beta_{TM} = 0$	30.02	$\chi_7^2 = 14.07$
8. $\beta_M = \beta_{LM} = \beta_{CM} = \beta_{MM} = \beta_{TM} = 0$	23.65	$\chi_5^2 = 11.07$
9. $\delta_M = \delta_{MT} = 0$	14.09	$\chi_2^2 = 5.99$
10. $\delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = \delta_{MT} = \delta_T = 0$	25.69	$\chi_7^2 = 14.07$
11. $\delta_{OPNT} = \delta_{SAVT} = \delta_{GDIT} = \delta_{TRDT} = \delta_{EXRT} = \delta_{MT} = 0$	20.85	$\chi_7^2 = 12.59$
12. $\delta_{MT} = 0$	7.16	$\chi_1^2 = 3.84$
13. $\beta_T = \beta_{TT} = \beta_{LT} = \beta_{CT} = \beta_{MT} = 0$	38.36	$\chi_5^2 = 11.07$
14. $\beta_{LT} = \beta_{CT} = \beta_{MT} = 0$	21.06	$\chi_3^2 = 7.82$
15. $\beta_{TM} = 0$	7.16	$\chi_1^2 = 3.84$
16. $\beta_L + \beta_C = 1, \beta_{LL} + \beta_{LC} = 0, \beta_{LC} + \beta_{CC} = 0$	8.41	$\chi_3^2 = 7.82$
17. $\beta_{LM} = \beta_{CM} = 0$	16.97	$\chi_2^2 = 5.99$

M stands for real money supply, *T* for a simple time-trend, *C* for physical capital, *L* for labour, *OPN* for countrys' openness to trade, *SAV* for total savings, *GDI* for gross domestic investments, *TRD* for total trade and, *EXR* for real exchange rate.

Note: When the null hypothesis involves the restriction of *γ*=0 then the LR-test statistic follows a mixed chi-squared distribution, the critical values of which are obtained from Kodde and Palm (1986, table 1).

Table 3
Time Development of Production Elasticities, Technical Change and Technical Efficiency Ratings

Year	Output Elasticities			RTS	Technical Change			Technical
	Labour	Capital	Money		Total	Neutral	Biased	Efficiency
1965	0.5840	0.2988	0.2651	1.1479	1.3514	2.1723	-0.8208	60.61
1966	0.5832	0.2958	0.2619	1.1409	1.3490	2.1527	-0.8037	60.58
1967	0.5824	0.2928	0.2588	1.1341	1.3454	2.1332	-0.7877	61.01
1968	0.5817	0.2906	0.2557	1.1280	1.3428	2.1136	-0.7708	62.54
1969	0.5809	0.2872	0.2530	1.1211	1.3362	2.0941	-0.7579	62.89
1970	0.5800	0.2838	0.2502	1.1140	1.3306	2.0745	-0.7440	60.71
1971	0.5791	0.2802	0.2477	1.1070	1.3233	2.0550	-0.7317	62.39
1972	0.5784	0.2779	0.2442	1.1006	1.3227	2.0354	-0.7128	63.21
1973	0.5781	0.2785	0.2398	1.0963	1.3305	2.0159	-0.6854	62.27
1974	0.5780	0.2814	0.2341	1.0935	1.3500	1.9963	-0.6464	63.17
1975	0.5773	0.2797	0.2299	1.0868	1.3558	1.9768	-0.6210	62.97
1976	0.5763	0.2759	0.2265	1.0787	1.3538	1.9572	-0.6034	62.42
1977	0.5755	0.2732	0.2229	1.0715	1.3537	1.9377	-0.5840	63.54
1978	0.5746	0.2700	0.2193	1.0639	1.3532	1.9181	-0.5650	63.96
1979	0.5744	0.2721	0.2137	1.0602	1.3717	1.8986	-0.5269	64.21
1980	0.5743	0.2745	0.2086	1.0574	1.3868	1.8791	-0.4922	65.01
1981	0.5735	0.2709	0.2063	1.0507	1.3757	1.8595	-0.4838	65.02
1982	0.5730	0.2703	0.2028	1.0461	1.3769	1.8400	-0.4631	65.36
1983	0.5727	0.2702	0.1999	1.0427	1.3731	1.8204	-0.4473	66.32
1984	0.5725	0.2712	0.1971	1.0409	1.3689	1.8009	-0.4320	66.98
1985	0.5724	0.2719	0.1949	1.0392	1.3604	1.7813	-0.4209	67.24
1986	0.5717	0.2671	0.1951	1.0339	1.3279	1.7618	-0.4339	67.21
1987	0.5714	0.2668	0.1925	1.0307	1.3222	1.7422	-0.4201	66.03
1988	0.5712	0.2670	0.1904	1.0287	1.3104	1.7227	-0.4122	68.36
1989	0.5713	0.2694	0.1873	1.0281	1.3087	1.7031	-0.3945	68.96
1990	0.5706	0.2664	0.1812	1.0182	1.3180	1.6836	-0.3656	69.05
1991	0.5695	0.2588	0.1768	1.0051	1.3032	1.6640	-0.3608	70.23
1992	0.5683	0.2545	0.1725	0.9953	1.3083	1.6445	-0.3361	71.54
Mean	0.5758	0.2763	1.0729	0.2208	1.3376	1.9136	-0.5760	64.78

Table 4
Frequency Distribution of Technical Efficiency Ratings (mean values over countries and time)

Technical Efficiency (%)	Countries	%
<10	0	(0)
10-20	0	(0)
20-30	0	(0)
30-40	5	(6.33)
40-50	10	(12.66)
50-60	31	(39.24)
60-70	15	(18.99)
70-80	12	(15.19)
80-90	4	(5.06)
90-100	2	(2.53)
N	79	
Mean	64.78	
Min	30.36	
Max	98.41	

Table 5

Total Factor Productivity Growth Decomposition

Total Factor Productivity	1.4481	(100)
Technical Change	1.3376	(92.4)
Neutral	1.9136	(143.1)
Biased	-0.5760	(-43.1)
Money Balances	0.0826	(-14.3)
Other Inputs	-0.6586	(114.3)
Scale Effect	0.0028	(0.2)
Money Balances	0.0008	(29.1)
Other Inputs	0.0020	(70.9)
Technical Efficiency	0.1078	(7.4)
Money Balances	0.0101	(9.4)
Other factors	0.0977	(90.6)

In parentheses are the corresponding percentage values.

Endnotes

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[1] Huang and Liu (1994) in their original formulation used the parameterization of the likelihood function suggested by Aigner *et al.*, (1977) and the predictor developed by Jondrow *et al*., (1982)

[2] This indirect effect of real money balances on TFP growth through the intertemporal changes in technical inefficiency can be also identified within Huang and Liu's (1994) non-neutral specification even in the case of a strongly separable functional specification (e.g. Cobb-Douglas).

[3] If strongly separability of the production technology is assumed but input-biased technical change is maintained, then the indirect effect of real money balances within the primal rate of technical change can be also identified. However, in cases that Hicks neutral technical change is imposed the last two terms in (10) vanishes.

[4] Output elasticity is a local directional measure evaluated at a point on the production frontier (Førsund, 1996; Balk, 1998, p. 18-19). Thus, (11a) do not contain the indirect effect of real money balances through their impact on technical inefficiency since at the frontier it is implied that u_{it}=0.

[5] The identification of this indirect effect of real money balances on TFP growth is only possible with non-homothetic functional specifications of the production frontier model in (6).

[6] The countries included in the sample were: Argentina, Australia, Austria, Belgium, Bolivia, Botswana, Canada, Switzerland, Chile, Cote d'Ivoire, Colombia, Denmark, Dominican Republic, Ecuador, Spain, Finland, France, United Kingdom, Greece, Hong Kong, Honduras, India, Ireland, Iran, Iceland, Israel, Italy, Jamaica, Japan, Kenya, Korea, Rep., Luxembourg, Morocco, Madagascar, Mexico, Mauritius, Malawi, Nigeria, Netherlands, Norway, New Zealand, Panama, Philippines, Portugal, Sierra Leone, Sweden, Syria, Tunisia, Turkey, Taiwan, United States, Venezuela, Zambia and, Zimbabwe.

[7] Due to the assumption of truncated half-normal distribution, the variance of u_{it} is equal to $[(\pi-2)/\pi]\sigma_u^2$ and not σ_u^2 (Greene, 1999, p.).

[8] Hypotheses testing was performed using the conventional generalized likelihood-ratio (LR) test. The test approximately follows a *chi-squared* distribution except in the case where the null hypothesis involves the restriction that γ=0 (Coelli, 1995).

Then, it follows a *mixed chi-squared* distribution the critical values of which are obtained from Kodde and Palm (1986).

[9] If the ratio-parameter, γ, equals zero, the model reduces to an average response function in which the variables of the inefficiency effects model can be included directly in the production function. In this case the constant (δ_0), the parameter associated with real money supply (δ_M), the interaction term with time (δ_{MT}) and, the parameter associated with temporal pattern of technical inefficiency (δ_T) cannot be identified as they are already included in the production frontier model. Thus, the number of restrictions for the chi-squared test statistic in the second hypothesis of Table 2 is five.