APPENDIX

Appendix A1: Technical efficiency in panel frontier models

Two types of panel data production frontier models can be adopted in measuring technical efficiency. In the first, technical efficiency is allowed to vary across industries, but is assumed constant through time for each industry. However, the assumption of time invariance of technical efficiency may be weak in long panels. The second type of panel data production frontier models allows technical efficiency to vary across industries and through time for each industry. Kumbhakar and Lovell (2000:97) provide a detailed discussion regarding panel frontiers.

A1.1 Time-invariant technical efficiency

Since observations exist on I industries indexed $i = 1,....,I$ by through T time periods, indexed by $t = 1,...,T$. A Cobb-Douglas production frontier with time invariant technical efficiency can be written as:

$$\ln Y_{it} = \alpha_0 + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_i , \qquad \text{A.1}$$

Where v_{it} represents random statistical noise and $\mu_i \geq 0$ represents technical inefficiency. The structure of the production function is assumed to be constant through time and no allowance is made for technical change. In essence, this model is similar to the cross-section production frontier except for the addition of time subscripts to output, inputs and to the statistical noise. The parameters of the model and technical efficiency can be estimated in a number of ways[54].

[54] It should be pointed out that maximum likelihood estimation of panel data estimation of a stochastic production frontier panel data with time invariant technical efficiency is structurally similar to the procedure followed in cross-sectional data.

(a). Fixed effects model

This is the simplest panel model to estimate. In order to adapt this model to the efficiency measurement the requirement that $\mu_i \geq 0$ has to be met. It is further assumed that v_{it} are $iid\left(0, \sigma_v^2\right)$ and are uncorrelated with the regressors. No distributional assumption is required for the μ_i, it can be correlated with the regressors or with v_{it}. Since μ_i are treated as fixed or non-random, they become industry specific intercept parameters to be estimated along with the α_n s. This model can be estimated by OLS in the form:

$$\ln Y_{it} = \alpha_{0i} + \sum_n \alpha_n \ln X_{nit} + v_{it}, \qquad \text{A.2}$$

Where the $\alpha_{0i} = \left(\alpha_0 - u_i\right)$ are the industry-specific intercepts. Estimation is accomplished either by suppressing α_0 and estimating I industry specific intercepts or by retaining α_0 and estimating $\left(I - 1\right)$ industry-specific intercepts or by applying a within transformation, in which all data are expressed in terms of deviations from industry means and the I intercepts are recovered as means of industry residuals[55]. A normalisation is employed after estimation in which:

$$\hat{\alpha}_0 = \max_i \left\{\hat{\alpha}_{0i}\right\} \qquad \text{A.3}$$

and the resultant μ_i is derived from:

$$\hat{\mu}_i = \hat{\alpha}_0 - \hat{\alpha}_{0i} \qquad \text{A.4}$$

this ensures that all $\hat{\mu}_i \geq 0$ and the industry-specific estimates of technical efficiency are then given by:

$$TE_i = \exp\left\{-\hat{\mu}_i\right\} \qquad \text{A.5}$$

In a fixed-effects model one industry will be 100 per cent technically efficient, and the technical efficiencies of others are computed relative to the technically

[55] Each of these variants is referred to as the least squares dummy variables (LSDV).

efficient industry. The fixed effects model is simple and has nice consistency properties for the industry-specific technical efficiency. The drawback is that while the fixed effects (μ_i) are intended to capture variation across industries in time-invariant technical efficiency, they also capture the effects of all phenomena that vary across industries but are time invariant for each industry.

(b). Random effects model

In this model the μ_i are randomly distributed with constant mean and variance, are assumed to be uncorrelated with the regressors and with the v_{it}. No distributional assumptions are made regarding μ_i only that it should be non negative. The v_{it} are required as before to have zero expectation and constant variance. This modification allows for the inclusion of time-invariant regressors in the model and the model can be written as:

$$\ln Y_{it} = [\alpha_0 - E(\mu_i)] + \sum_n \alpha_n \ln X_{nit} + v_{it} - [\mu_i - E(\mu_i)]$$

$$= \alpha_0^* + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_i^* \qquad \text{A.6}$$

where the underlying assumption that the μ_i are random rather than fixed permits some of the X_{nit} to be time invariant. This random effects model fits into the one way error components model in panel data literature and can be estimated by the standard two step generalised least squares GLS method. Once α_0^* and $\alpha_n s$ have been estimated using feasible GLS, the μ_i^* can be generated from the residuals by means of equation A.7 below:

$$\hat{\mu}_i^* = \frac{1}{T} \sum_t \left(\ln Y_{it} - \hat{\alpha}_0^* - \sum_n \hat{\alpha}_n \ln X_{nit} \right) \qquad \text{A.7}$$

Estimates of μ_i are again obtained by means of normalisation such that:

$$\hat{\mu}_i = \max_i \{\hat{\mu}_i^*\} - \hat{\mu}_i^* \qquad \text{A.8}$$

The estimates will be consistent as both T and I tend to infinity. Estimates of industry-specific technical efficiency are then obtained by substituting $\hat{u}_i$ into equation A.5. In tune with the fixed effects model, estimators for the random effects model also require that at least one industry be 100 per cent technically efficiency so that the technical efficiencies of the remaining industries are measured relative to the technically efficient industries.

A1.1 Time-varying technical efficiency

The assumption that technical efficiency is constant through time is very strong in operating environments that are competitive. Technical inefficiency cannot remain constant for long time periods. While it is desirable to relax this assumption, the relaxation however, happens only at the cost of additional parameters to be estimated. Two approaches have been followed in the estimation of the time-varying technical efficiency model. The first approach has time-varying technical efficiency modelled using fixed or random effects and the second by maximum likelihood approach or method of moments[56].

(a) Fixed effects and random effects models

Cornwell, Schmidt, and Sickles (1990) and Kumbhakar (1990) proposed a stochastic production panel data model with time-varying technical efficiency. The model is specified as:

$$\ln Y_{it} = \alpha_{0t} + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_{it}$$

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[56] If the independence and distributional assumptions are tenable, then it is possible to use maximum likelihood estimation. It is also possible to estimate parameters in equation A.9 using method of moments.

$$= \alpha_{it} + \sum_{n} \alpha_n \ln X_{nit} + v_{it} \qquad \text{A.9}$$

where α_{0t} is the production frontier intercept common to all industries in period t, $\alpha_{it} = \alpha_{0t} - \mu_{it}$ is the intercept for industry i in period t, the remainder of the variables are as previously defined. With an $I \times T$ panel it is not possible to obtain estimates of all $I \bullet T$ intercepts α_{it}, the N slope parameters α_n and σ_v^2. Cornwell, Schmidt, and Sickles (1990) addressed this problem by specifying:

$$\alpha_{it} = \Omega_{i1} + \Omega_{i2} t + \Omega_{i3} t^2 \qquad \text{A.10}$$

While this reduces the number of intercepts to be estimated, Lee and Schmidt (1993) proposed an alternative specification in which the μ_{it} in equation A.9 are specified as:

$$\mu_{it} = \alpha(t) \bullet \mu_i \qquad \text{A.11}$$

Where the function $\alpha(t)$ is specified as a set of time dummy variables α_t. This model is appropriate for short panels. Once the $\alpha_t s$ and μ_i are estimated, then

$$\mu_{it} = \sum_{i} \{\hat{\alpha}_t \hat{\mu}_i\} - (\hat{\alpha}_t \hat{\mu}_i) \text{ and } TE = \exp\{-\hat{\mu}_{it}\} \qquad \text{A.12}$$

Appendix A2: The Battese and Coelli (1992) specification

Maximum likelihood estimates of stochastic frontier production functions for panel data with time-varying or invariant efficiencies in the spirit of Battese and Coelli (1992) can be estimated. In particular, Battese and Coelli (1992) propose a stochastic frontier production function for panel data which has firm effects that are assumed to be distributed as truncated normal random variables, and are permitted to vary systematically with time. The model may be expressed as:

$$Y_{it} = x_{it}\alpha + (\nu_{it} - \mu_{it}) \quad i = 1,...., N, t = 1,..., T, \qquad \text{A13}$$

where Y_{it} is the logarithm of the output of the i-th industry in the t-th time period; x_{it} is a $k \times 1$ vector of inputs of the i-th industry in the t-th time period; α is a vector of unknown parametes; the ν_{it} are random variables which are assumed to be iid $N(0, \sigma\nu^2)$, and independent of the $\mu_{it} = (\mu_i \exp(-\eta(t-T)))$, where the μ_i are non-negative random variables that are assumed to account for technical inefficiency in production and are assumed to be iid as truncations at zero of the $N(\mu, \sigma\mu^2)$ distribution; η is a parameter to be estimated; and the panel of data need not be complete.

Coelli (1996) utilises the parameterization of Battese and Corra (1977) to replace $\sigma\nu^2$ and $\sigma\mu^2$ with $\sigma^2 = \sigma\nu^2 + \sigma^2\mu^2$ and $\gamma = \dfrac{\sigma\mu^2}{(\sigma\nu^2 + \sigma\mu^2)}$ in the context ofe maximum likelihood estimation. The parameter, γ, lies between 0 and 1 and this range is searched to provide a good starting value for use in an iterative maximization process. The log-likelihood function of this model is presented in Battese and Coelli (1992).

The imposition of restrictions upon model A.13 can provide a number of the special cases of this particular model which have appeared in the literature such as Battese, Coelli and Colby (1989), Battese and Coelli (1988), Pitt and Lee (1981), Aigner, Lovell and Schmidt (1977) as well as Stevenson (1980. Predictions of individual industry technical efficiencies from stochastic production frontiers can be derived in which the measures of technical efficiency relative to the production frontier (A13) are defined as:

$$EFF_i = E\left(Y_i^* \mid \mu_i, X_i / E\left(Y_i^* \mid \mu_i = 0, X_i\right)\right) \qquad \text{A14}$$

where Y_i^* is the production of the i-th industry, which will be equal to $\exp(Y_i)$ when the dependent variable is in logs. The EFF_i will take a value between zero and one. The results of implementing the Battese and Coelli (1992) specification produces estimates in Table A2.1 and A2.2 below and efficiency estimates are found in Table A2.3 and Table A2.4. These results employ output rather than value added for the Cobb-Douglas and translog functions respectively.

Table A2.1: Maximum Likelihood Estimates: Cobb-Douglas production function

Stochastic frontier model: Dependent Variable ln(y)				
Variable	**Parameter**	**Coefficient**	**Standard error**	**t-ratio**
$\ln(K)$	α_k	0.1466	0.0355	4.12
$\ln(N)$	α_n	0.2162	0.0280	7.71
$\ln(M)$	α_m	0.4507	0.0225	20.04
t	α_t	0.0120	0.0020	6.17
Constant	α_0	1.9121	0.1409	13.57
Sigma-squared	σ^2	0.2873	0.0464	6.19
Gamma	γ	0.9501	0.0093	102.60
mu	μ	-0.1026	0.1889	-0.54
eta	η	-0.1643	0.0035	-4.68
Log likelihood function	366.1463			
LR test of one sided error	1076.8774			
Maximum no. of iterations	100			
No. of cross sections	28			
No. of time periods	23			
Total no. of observations	644			

Note: Error components specification using output rather than value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.2: Maximum Likelihood Estimates: Translog production function

Stochastic frontier model: Dependent Variable ln(y)				
Variable	**Parameter**	**Coefficient**	**Standard error**	**t-ratio**
$\ln(K)$	α_k	0.5805	0.2297	2.53
$\ln(N)$	α_n	0.3995	0.2366	1.69
$\ln(M)$	α_m	-0.2552	0.2059	-1.24
t	α_t	0.0345	0.0089	3.84
$\ln(K) \times \ln(N)$	β_{kn}	0.0457	0.0237	1.93
$\ln(K) \times \ln(M)$	β_{km}	-0.1254	0.0304	-4.12
$\ln(K) \times (t)$	β_{kt}	0.0058	0.0012	4.94
$\ln(N) \times \ln(M)$	β_{nm}	-0.2273	0.0260	-8.73
$\ln(N) \times (t)$	β_{nt}	-0.0008	0.0011	-0.74
$\ln(M) \times (t)$	β_{mt}	-0.0070	0.0017	-4.05
$(\frac{1}{2})\ln(K^2)$	β_{kk}	0.0054	0.0327	0.17
$(\frac{1}{2})\ln(N^2)$	β_{nn}	0.1341	0.0319	4.21
$(\frac{1}{2})\ln(M^2)$	β_{mm}	0.4995	0.0450	11.09
$(\frac{1}{2})\ln(t^2)$	β_{tt}	-0.0003	0.0002	-1.25
Constant	α_0	1.6830	1.1193	1.41
Sigma-squared	σ^2	0.3078	0.0400	7.69
Gamma	γ	0.9627	0.0039	248.07
mu	μ	-0.0109	0.4107	-2.65
eta	η	-0.0163	0.0025	-6.47
Log likelihood function	479.2915			
LR test of one sided error	1099.3067			
Maximum no. of iterations	100			
No. of cross sections	28			
No. of time periods	23			
Total no. of observations	644			

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.3 : Cobb Douglas function technical efficiency Estimates

Industry	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
S_301	0.939	0.938	0.937	0.936	0.935	0.934	0.932	0.931	0.930	0.929	0.928	0.927	0.926	0.925	0.923	0.922	0.921	0.920	0.918	0.917	0.916	0.915	0.913
S_305	0.807	0.804	0.801	0.798	0.795	0.792	0.789	0.786	0.783	0.779	0.776	0.773	0.770	0.766	0.763	0.760	0.756	0.753	0.749	0.746	0.742	0.738	0.735
S_306	0.983	0.983	0.983	0.982	0.982	0.982	0.982	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.977	0.976
S_311	0.640	0.635	0.630	0.625	0.621	0.616	0.611	0.606	0.601	0.596	0.591	0.585	0.580	0.575	0.570	0.565	0.559	0.554	0.549	0.543	0.538	0.532	0.527
S_313	0.653	0.649	0.644	0.639	0.634	0.630	0.625	0.620	0.615	0.610	0.605	0.600	0.595	0.590	0.585	0.580	0.575	0.569	0.564	0.559	0.553	0.548	0.543
S_316	0.562	0.557	0.552	0.546	0.541	0.535	0.530	0.524	0.519	0.513	0.507	0.502	0.496	0.490	0.485	0.479	0.473	0.467	0.461	0.455	0.450	0.444	0.438
S_317	0.579	0.574	0.569	0.564	0.558	0.553	0.548	0.542	0.537	0.531	0.526	0.520	0.514	0.509	0.503	0.498	0.492	0.486	0.480	0.474	0.469	0.463	0.457
S_321	0.639	0.634	0.629	0.624	0.620	0.615	0.610	0.605	0.600	0.595	0.590	0.584	0.579	0.574	0.569	0.564	0.558	0.553	0.547	0.542	0.537	0.531	0.525
S_323	0.822	0.819	0.816	0.813	0.811	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.764	0.761	0.758	0.754
S_324	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.764	0.761	0.758	0.754	0.751	0.747	0.743	0.740	0.736	0.732	0.729	0.725
S_331	0.689	0.685	0.681	0.677	0.672	0.668	0.663	0.659	0.654	0.650	0.645	0.640	0.636	0.631	0.626	0.621	0.616	0.612	0.607	0.602	0.597	0.591	0.586
S_334	0.814	0.812	0.809	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.782	0.779	0.776	0.772	0.769	0.766	0.762	0.759	0.756	0.752	0.749	0.745
S_335	0.848	0.845	0.843	0.841	0.838	0.836	0.833	0.831	0.828	0.826	0.823	0.820	0.818	0.815	0.812	0.809	0.807	0.804	0.801	0.798	0.795	0.792	0.789
S_337	0.623	0.618	0.613	0.608	0.603	0.598	0.593	0.588	0.583	0.578	0.573	0.567	0.562	0.557	0.551	0.546	0.540	0.535	0.529	0.524	0.518	0.513	0.507
S_338	0.720	0.716	0.712	0.708	0.704	0.700	0.696	0.692	0.687	0.683	0.679	0.674	0.670	0.666	0.661	0.657	0.652	0.647	0.643	0.638	0.633	0.629	0.624
S_341	0.560	0.555	0.550	0.544	0.539	0.533	0.528	0.522	0.517	0.511	0.505	0.500	0.494	0.488	0.483	0.477	0.471	0.465	0.459	0.453	0.447	0.442	0.436
S_342	0.598	0.593	0.588	0.583	0.578	0.572	0.567	0.562	0.556	0.551	0.546	0.540	0.535	0.529	0.524	0.518	0.512	0.507	0.501	0.495	0.490	0.484	0.478
S_351	0.811	0.808	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.781	0.778	0.775	0.772	0.769	0.765	0.762	0.758	0.755	0.751	0.748	0.744	0.741
S_352	0.839	0.837	0.834	0.832	0.829	0.827	0.824	0.821	0.819	0.816	0.813	0.810	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.777
S_353	0.860	0.858	0.856	0.854	0.851	0.849	0.847	0.844	0.842	0.840	0.837	0.835	0.832	0.830	0.827	0.825	0.822	0.819	0.817	0.814	0.811	0.808	0.806
S_356	0.922	0.921	0.919	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.907	0.906	0.904	0.903	0.901	0.900	0.898	0.897	0.895	0.893	0.892	0.890
S_361	0.813	0.811	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.765	0.761	0.758	0.754	0.751	0.747	0.744
S_371	0.767	0.763	0.760	0.756	0.753	0.749	0.746	0.742	0.738	0.735	0.731	0.727	0.723	0.720	0.716	0.712	0.708	0.704	0.700	0.695	0.691	0.687	0.683
S_374	0.696	0.692	0.688	0.684	0.680	0.675	0.671	0.666	0.662	0.657	0.653	0.648	0.644	0.639	0.634	0.630	0.625	0.620	0.615	0.610	0.605	0.600	0.595
S_381	0.976	0.975	0.975	0.974	0.974	0.974	0.973	0.973	0.972	0.972	0.971	0.971	0.970	0.970	0.970	0.969	0.969	0.968	0.967	0.967	0.966	0.966	0.965
S_384	0.905	0.903	0.902	0.900	0.899	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.884	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866
S_391	0.702	0.698	0.694	0.690	0.686	0.681	0.677	0.673	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.636	0.632	0.627	0.622	0.617	0.612	0.607	0.602
S_392	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean effic. in year	0.770	0.767	0.764	0.761	0.758	0.754	0.751	0.748	0.744	0.741	0.737	0.734	0.730	0.727	0.723	0.720	0.716	0.713	0.709	0.705	0.701	0.698	0.694

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.4 : Translog Production function technical efficiency estimates

Industry	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
S_301	0.900	0.898	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.883	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860
S_305	0.881	0.879	0.877	0.875	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.859	0.857	0.855	0.853	0.851	0.848	0.846	0.844	0.842	0.839	0.837	0.834
S_306	0.983	0.982	0.982	0.982	0.981	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.976	0.976	0.976	0.975
S_311	0.737	0.733	0.729	0.726	0.722	0.718	0.714	0.710	0.706	0.702	0.698	0.694	0.690	0.686	0.681	0.677	0.673	0.668	0.664	0.660	0.655	0.651	0.646
S_313	0.722	0.718	0.714	0.710	0.706	0.702	0.698	0.694	0.690	0.685	0.681	0.677	0.673	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.637	0.632	0.627
S_316	0.739	0.735	0.732	0.728	0.724	0.720	0.717	0.713	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671	0.667	0.662	0.658	0.654	0.649
S_317	0.706	0.702	0.698	0.694	0.690	0.685	0.681	0.677	0.672	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.636	0.632	0.627	0.622	0.617	0.612	0.608
S_321	0.735	0.731	0.728	0.724	0.720	0.716	0.712	0.708	0.704	0.700	0.696	0.692	0.688	0.684	0.680	0.675	0.671	0.666	0.662	0.658	0.653	0.649	0.644
S_323	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.883	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860	0.858	0.856
S_324	0.937	0.936	0.935	0.934	0.933	0.931	0.930	0.929	0.928	0.927	0.926	0.925	0.924	0.922	0.921	0.920	0.919	0.917	0.916	0.915	0.913	0.912	0.911
S_331	0.869	0.867	0.865	0.863	0.861	0.859	0.857	0.855	0.852	0.850	0.848	0.846	0.843	0.841	0.839	0.836	0.834	0.831	0.829	0.826	0.824	0.821	0.818
S_334	0.964	0.964	0.963	0.962	0.962	0.961	0.961	0.960	0.959	0.959	0.958	0.957	0.957	0.956	0.955	0.955	0.954	0.953	0.952	0.952	0.951	0.950	0.949
S_335	0.970	0.970	0.969	0.969	0.968	0.968	0.967	0.967	0.966	0.966	0.965	0.965	0.964	0.964	0.963	0.962	0.962	0.961	0.961	0.960	0.959	0.959	0.958
S_337	0.757	0.753	0.750	0.746	0.743	0.739	0.735	0.732	0.728	0.724	0.720	0.717	0.713	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671
S_338	0.835	0.832	0.830	0.827	0.825	0.822	0.819	0.817	0.814	0.811	0.808	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.782	0.779	0.775	0.772
S_341	0.678	0.674	0.670	0.665	0.661	0.657	0.652	0.647	0.643	0.638	0.633	0.629	0.624	0.619	0.614	0.609	0.605	0.600	0.595	0.589	0.584	0.579	0.574
S_342	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671	0.667	0.662	0.658	0.653	0.649	0.644	0.640	0.635	0.630	0.626	0.621	0.616	0.611
S_351	0.947	0.947	0.946	0.945	0.944	0.943	0.942	0.941	0.940	0.939	0.938	0.937	0.936	0.935	0.934	0.933	0.932	0.931	0.930	0.929	0.928	0.927	0.926
S_352	0.982	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.977	0.976	0.976	0.975	0.975	0.975	0.974	0.974
S_353	0.929	0.928	0.927	0.926	0.924	0.923	0.922	0.921	0.919	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.907	0.906	0.905	0.903	0.902	0.900
S_356	0.972	0.971	0.971	0.971	0.970	0.970	0.969	0.969	0.968	0.968	0.967	0.967	0.966	0.965	0.965	0.964	0.964	0.963	0.963	0.962	0.961	0.961	0.960
S_361	0.918	0.916	0.915	0.914	0.912	0.911	0.910	0.908	0.907	0.905	0.904	0.902	0.901	0.899	0.898	0.896	0.895	0.893	0.891	0.890	0.888	0.886	0.884
S_371	0.931	0.930	0.929	0.928	0.927	0.926	0.924	0.923	0.922	0.921	0.920	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.908	0.906	0.905	0.903
S_374	0.887	0.885	0.883	0.881	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860	0.858	0.856	0.853	0.851	0.849	0.847	0.844	0.842
S_381	0.834	0.831	0.829	0.826	0.823	0.821	0.818	0.815	0.813	0.810	0.807	0.804	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.780	0.777	0.774	0.771
S_384	0.988	0.987	0.987	0.987	0.987	0.986	0.986	0.986	0.986	0.986	0.985	0.985	0.985	0.985	0.984	0.984	0.984	0.984	0.983	0.983	0.983	0.982	0.982
S_391	0.788	0.785	0.782	0.779	0.776	0.773	0.769	0.766	0.763	0.759	0.756	0.753	0.749	0.746	0.742	0.738	0.735	0.731	0.727	0.723	0.720	0.716	0.712
S_392	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean effic. in year	0.864	0.862	0.860	0.858	0.856	0.854	0.852	0.850	0.848	0.845	0.843	0.841	0.839	0.837	0.834	0.832	0.830	0.827	0.825	0.822	0.820	0.817	0.815

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Appendix A3: Variable definitions

Variable	Definition
Africa_mz	Value of imports from the African region in millions of Rand
America_mz	Value of imports from the American region in millions of Rand
Asia_mz	Value of imports from the Asian region in millions of Rand
CAP	The percentage utilisation of production capacity. Therefore 100 percent would refer to full capacity utilisation.
CPI	Consumer price index 1995=100
DD	Domestic demand is equal to total output plus imports minus exports. The import-domestic demand ratio is an indication of how much of the domestic demand is satisfied by imports.
EX	The export-output ratio is a measure of how much of South Africa's industrial output is exported. The export-output ratio is equal to total exports (X) divided by total output (Q) of an industry times one hundred: Export-output ratio = (X / Q)*100.
Europe_mz	Value of imports from the European region in millions of Rand
Fixed capital productivity	Fixed capital productivity is a measure of output per unit of fixed capital input. Fixed capital productivity is equal to total output (Q) divided by the fixed capital input (C), i.e. the capital stock: Fixed capital productivity = Q / C = output per unit of fixed capital input.
GM	The gross mark-up of an industry is the net operating surplus of that industry as a percentage of total intermediate inputs plus labour remuneration for that industry. It excludes all net indirect taxes.
Gross domestic fixed investment	Gross domestic fixed investment consists of buildings and construction works, transport equipment, machinery and other equipment and transfer costs
IM	Intermediate imports refer to the imports of goods and services produced elsewhere in the world, but used in the industry of the country under consideration and consumed in the production process. Intermediate imports exclude the importation of production factors.
K	Fixed capital stock consists of buildings and construction works, transport equipment, machinery and other equipment and transfer costs.
Labour productivity	Labour productivity is the ratio between output (Q) and the labour input (LI) used to produce that output: Labour productivity = Q / LI = output per unit of labour input. Labour productivity can be expressed as output per worker (by dividing total output by total number of workers employed.
M	Value of materials input in millions of Rand.
MS	Proportion of industry sales to total manufacturing sector sales
MZ	The import-domestic demand ratio or import penetration is equal to total imports (Z) divided by total domestic demand (DD) times one hundred: Import-domestic demand ratio = (Z / DD)*100.
MZ1	Import leakage is a measure of how much is imported to satisfy local demand. Import leakage is equal to total imports (Z) divided by total imports added total output (Q) times one hundred: Import leakage = [Z / (Z + Q)]*100.
N	Employment figures indicate the number of paid employees and include casual and seasonal workers. Employment consists of three main categories, namely highly skilled, skilled and semi-and unskilled labour.
oceania_mz	Value of imports from the Oceania region in millions of Rand
RAD	Expenditure by industries on machinery and equipment in

Variable	Definition
	millions of Rand.
RAD1	Ratio of expenditure by industries on machinery and equipment to total gross domestic investment
RER	Rand real exchange rate 1995=100
SKILL	Ratio of skilled employees to total number of employees
TARIFF	Ratio of customs duties paid by industry to total imports
TE	Technical efficiency scores
TOT	Terms of trade index 1995=100
V	Value added= Value added at basic prices + Net indirect taxes on products (by government).
Y	Final output of goods by industry used or consumed by individuals, households and firms and not processed further or resold

Notes: Where necessary nominal variables are deflated with an appropriate price index to obtain real series.

Source:http://ts.easydata.co.za;http://www.tips.org.za;http://www.resbank.co.za; http://www.statssa.gov.za