Risk Adjusted Productivity Measures

Anna Glazyrina
Dept. of Agribusiness and Applied Economics
NDSU, Fargo, ND 58108-6050
E-mail: anna.glazyrina@ndsu.edu

Saleem Shaik[1]
504 Richard H Barry Hall
Dept. of Agribusiness and Applied Economics
NDSU, Fargo, ND 58108-6050
Phone: (701) 231 7459; Fax: (701) 231 7400
E-mail: saleem.shaik@ndsu.edu

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[1] Corresponding author.

Risk Adjusted Productivity Measures

Introduction

Any production related activity or event that is uncertain with probability is defined as risk. Production theory of the firm under risk is well developed and has been traditionally analyzed under price risk (Chambers, 1983; and Sandmo, 1971) or production risk (Just and Pope, 1978). In agriculture for decades, risk has been most strongly identified with production (income) risk and product price risk with less attention to input and input price risk. Variability in production (income) results in the inability to achieve goal. Over time, improvements in technology and production practices have helped decrease risks in agriculture by increasing (decreasing) the first (second) moment of yields. Currently farmers deal with risk by controlling or minimizing risk through improved and efficient management practices; reduce variability by making changes such as diversifying and integrating, and applying updated technology; and finally they transfer production risk to someone else through contracting or purchasing crop insurance.

Here neoclassical production theory along with decision theory is applied to explore the impact of risk on agriculture producers who maximize utility and face production functions. Including risk in efficiency paradigm is relatively an unexplored area of research, specifically estimation of risk jointly with output production function. Risk is generally characterized as an objective perspective based on long run phenomena. In most cases a longer run data source is preferred over a shorter run one. On the other hand, changing technical and economic environments favor shorter run data sets. For example, crop yields of one hundred years ago as part of a crop yield data set can be argued to be irrelevant to a crop yield risk analysis. In addition risk in agriculture is sometimes suggested to be a changing phenomenon as technical and economic environments change. When the issue of behavioral responses to recent events is added the issue of risk, as a changing parameter is even more important. The "recent event" phenomenon suggests that risk is most strongly evaluated by the most recent events experienced. A current crop loss, for example, would be expected to strongly increase perceived risk compared to the same loss a decade ago.

For this reason the issue of the evaluation of the impact on productivity of risk is evaluated here using risk as a long run objective variable as well as a shorter run measure giving greater weight to recent events. This is accomplished here using the entire length of the series to the point of analysis for the former and an annually adjusted short run risk measure for the latter. In the first case (termed cumulative) more recent time periods have a larger risk since an additional year is added to the risk calculation for each year of efficiency analysis.

In agriculture for decades, risk has been most strongly identified with production risk and product price risk. On a broader basis, research on incorporating production risk can be categorized into two groups: those that concentrate on incorporating producer's behavior and attitude towards production risk and those that explicitly account for risk in the analysis. In the first category focusing on production risk (variance of output), econometric estimation of production function has been established by Just and Pope, 1978 followed by Love and Buccola, 1991 and 1999 who included producer's attitude towards risk, and finally Kumbhakar, 2002 included not only production risk and attitude towards risk but examined in the efficiency paradigm. Still existing literature falls short as production risk and attitude treated as endogenous and exogenous variables respectively has not been incorporated into efficiency analysis. The second category typically has examined the impact of risk on efficiency by explicitly incorporating risk in production function (Chang, 1999; Helmers and Shaik, 1999 and 2000; Shaik and Helmers, 2003).

The purpose of this paper is to estimate risk adjusted productivity measures for U.S. agriculture sector using graphic distance function framework. Specific objectives of the paper are to estimate the risk adjusted productivity measures accounting for long-run and alternative short-run production risk. The study uses panel state data for the U.S agricultural sector for the period, 1960-2004.

Nonparametric Risk Model

The technology that transforms input vector $x = (x_1, \ldots\ldots, x_n)$ into desirable outputs $y = (y_1, \ldots\ldots, y_m)$ and risk (variation in output) $R = (R_1, \ldots\ldots, R_o)$ can be represented by output set. With output set, efficiency is measured as the ability to increase output taking input quantities as given. Hence, an efficiency score above one indicate by how much the output (efficiency) can be increased (improved) given inputs. The output set is effectively utilized in the computation of the risk accounted efficiency measure using the primal approach. Risk endogenized as an undesirable output with a weak disposability assumption is modeled to compute the efficiency measure. Under a weak disposability risk assumption, a reduction in risk requires a reduction in desirable output with a fixed input or requires an increase in input usage to maintain the same desirable output.

Weak disposal output reference set satisfying constant returns to scale, strong disposability of desirable outputs and inputs, and weak disposability of risk can be defined as:

$$(1) \qquad P_w^T(x) = \left\{ \begin{array}{l} y : x \, can \; produce \; (y_g, R) \text{ in year } T; \\ 0 \le \theta \le 1 \; implies \; \theta(y_g, R) \in P_w^T(x) \quad R' < R \Rightarrow \theta(y_g, R') \in P_w^T(x) \end{array} \right\}$$

where $P_w^T(x)$ is a weak disposable output set.

The weak disposable output set can be represented by the output distance function and the nonlinear programming problem used to calculate the output measure can be evaluated for each state in year *t* as:

$$D_o^T\left(x^t, y_g^t, R^t \mid crs\right)^{-1} = \max_{\theta, z}\left\{\theta : \left(x^t, \theta y_g^t, \theta^{-1} R^t\right) \in P_w^T\left(x^t\right)\right\}$$

$$or$$

$$(2) \qquad \begin{aligned} \max_{\theta, z} \theta \quad s.t. \quad \theta y_g^t &\leq Y_g z & \text{where } Y_g &= \left(y_g^1, y_g^2, ..., y_g^T\right) \\ \theta^{-1} n^t &= R z & R &= \left(r^1, r^2, ..., r^T\right) \\ x^t &\geq X z & X &= \left(x^1, x^2, ..., x^T\right) \\ z &\geq 0 \end{aligned}$$

From (2), ***z*** is a $\{Tx1\}$ vector of intensity variables with $z \geq 0$ identifying the constant-return-to-scale boundaries of the reference set, and the equal sign on the second constraint indicates the weak disposability assumption on risk with a less than (greater than) sign representing the strong disposability of desirable output (input).

2.1 Panel Output-based Malmquist Productivity accounting for Risk

In a panel data series observations on a multiple decision making units (such as 48 states in the U.S), output-based Malmquist productivity OMP_{t-1}^t is defined as the geometric mean of four output distance functions based on current (t) and previous $(t-1)$ period technologies for k decision making units as:

$$(3) \qquad OMP_{t-1}^t = \sqrt{\frac{D^{t-1}(x^t, y_g^t, R^t)}{D^{t-1}(x^{t-1}, y_g^{t-1}, R^{t-1})} \frac{D^t(x^t, y_g^t, R^t)}{D^t(x^{t-1}, y_g^{t-1}, R^{t-1})}}$$

Under constant return to scale technology, productivity improvements will result in values of greater than one while values less than one signify productivity declines.

The OMP_{t-1}^{t} defined in equation (3) requires the estimation of two same-period (4a and 4b) distance functions:

(4a) $\left[D^t\left(x^t, y_g^t, R^t\right)\right]^{-1} = \max\left\{\theta : \left(\theta\, y_g^t, R^t\right) \in P\left(x^t\right)\right\}$

(4b) $\left[D^{t-1}\left(x^{t-1}, y_g^{t-1}, R^{t-1}\right)\right]^{-1} = \max\left\{\theta : \left(\theta\, y_g^{t-1}, R^{t-1}\right) \in P\left(x^{t-1}\right)\right\}$

and two mixed-period (4c and 4d) distance functions:

(4c) $\left[D^t\left(x^{t-1}, y_g^{t-1}, R^{t-1}\right)\right]^{-1} = \max\left\{\theta : \left(\theta\, y_g^{t-1}, R^{t-1}\right) \in P\left(x^t\right)\right\}$

(4d) $\left[D^{t-1}\left(x^t, y_g^t, R^t\right)\right]^{-1} = \max\left\{\theta : \left(\theta\, y_g^t, R^t\right) \in P\left(x^{t-1}\right)\right\}$

The same-period output based distance functions may be calculated as the solution to the linear programming problem

$$(5a)\quad \left[D^t\left(x^t, y_g^t, R^t\right)\right]^{-1} = \max_{\theta,z} \theta \quad s.t.\quad \theta\, y_g^t \le Y_g z,\quad \theta^{-1} n^t = R\, z,\quad x^t \ge X z,\quad z \ge 0$$

$$(5b)\quad \left[D^{t-1}\left(x^{t-1}, y_g^{t-1}, R^{t-1}\right)\right]^{-1} = \max_{\theta,z} \theta \quad s.t.\quad \theta\, y_g^{t-1} \le Y_g z,\quad \theta^{-1} n^{t-1} = R\, z,\quad x^{t-1} \ge X z,\quad z \ge 0$$

where the z's being the intensity variables with $z \ge 0$ identifying the constant return to scale boundaries of the reference set.

The mixed-period output based distance functions may be calculated as the solution to the linear programming problem

$$(5c)\quad \left[D^t\left(x^{t-1}, y_g^{t-1}, R^{t-1}\right)\right]^{-1} = \max_{\theta,z} \theta \quad s.t.\quad \theta\, y_g^{t-1} \le Y_g z,\quad \theta^{-1} n^{t-1} = R\, z,\quad x^{t-1} \ge X z,\quad z \ge 0$$

$$(5d)\quad \left[D^{t-1}\left(x^t, y_g^t, R^t\right)\right]^{-1} = \max_{\theta,z} \theta \quad s.t.\quad \theta\, y_g^t \le Y_g z,\quad \theta^{-1} n^t = R\, z,\quad x^t \ge X z,\quad z \ge 0$$

3. Data and variables used in the analysis

The U.S. Department of Agriculture's Economic Research Service (ERS) constructs and publishes the state and aggregate production accounts for the farm sector[2]. The features of the state and national production accounts are consistent with gross output model of production and are well documented in Ball et al. (1999). Output is defined as gross production leaving the farm, as opposed to real value added. Price of land is based on hedonic regressions. Specifically the price of land in a state is regressed against land characteristics and location (state dummy). Prices of capital inputs are obtained on investment goods prices, taking into account the flow of capital services per unit of capital stock in each state (Ball et al, 2001). Table 1 presents the summary statistics of the output, input and farm program payment risk variables.

4. Empirical application and results

To examine the productivity, efficiency and technical change of U.S. agriculture accounting for the long-run and two alternative short-run risk, the output distance function defined in equations 5 is estimated using 3 outputs, 6 input and 1 risk variable. Three models were estimated for three alternative measures of risk – long-run risk and two alternative short-run risk measures. Table 1 presents the average (over time) annual productivity, efficiency and technical change measures by state for the time-period, 1965-2004. Table 2 presents the average (across states) annual productivity, efficiency and technical change measures by year for the time-period, 1965-2004. Figure 1 and 2 presents the difference between long-run and short-run adjusted measures by state and year, respectively.

[2] The data are available at the USDA/ERS website http://www.ers.usda.gov/data/agproductivity/.

In general the average rate of change in the risk adjusted measures indicate reduced productivity, neutral efficiency change and reduced technical change when accounting for long-run risk. This indicates lower productivity and technical change gains when long-run risk is accounted in the estimation. Thus, long-run risk does not impact efficiency change measures as it is neutral with respect to efficiency. The standard deviation or rate of change across states indicated a low of 0.3 percent for efficiency change compared to around 7 percent for productivity and technical change measures. This is reflected in the wide range in the minimum and maximum rates of changes in the productivity and technical change measures.

Similar pattern is indicated for two alternative short-run risk adjusted measures. However the major difference compared to long-run risk is accounting for short-run risk measures actually increase the productivity, technical and efficiency change measures. The average rate of change in productivity, technical and efficiency measures for the five year short-run risk measures is 1.007, 1.001 and 1.008, respectively. The average rate of change in productivity, technical and efficiency measures for the five year short-run risk measures is 1, 1.001 and 1.001, respectively.

The difference between the difference between long-run and short-run adjusted measures by state and year, respectively are graphically represented in Figure 1 and 2. The differences are much more prevalent in the productivity and technical changes measures not only across states but also over time.

5. Conclusions

Utilizing the non-parametric linear programming approach, theoretically and empirically we demonstrate -the inclusion of risk in the productivity analyses would results in lower (higher) productivity gains for short-run (long-run) risk. Further for this data, the short-run risk adjusted productivity measures seem to perform better than long-run risk adjusted productivity measures. This research is directed only at production risk.

Where data is available the analysis completed here is useful technique in understanding gains from inclusion of risk. In integration traditional productivity studies with risk, either aggregate or individual firm data can be employed. Bootstrapping techniques can also be employed in association with DEA analysis to provide still greater confidence regarding the conclusion of these analyses. In addition, a larger data set with greater disaggregation of inputs would aid in deriving broad conclusions.

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Figure 1. Average differences between long and short-run risk-adjusted measures by state, 1965-2004

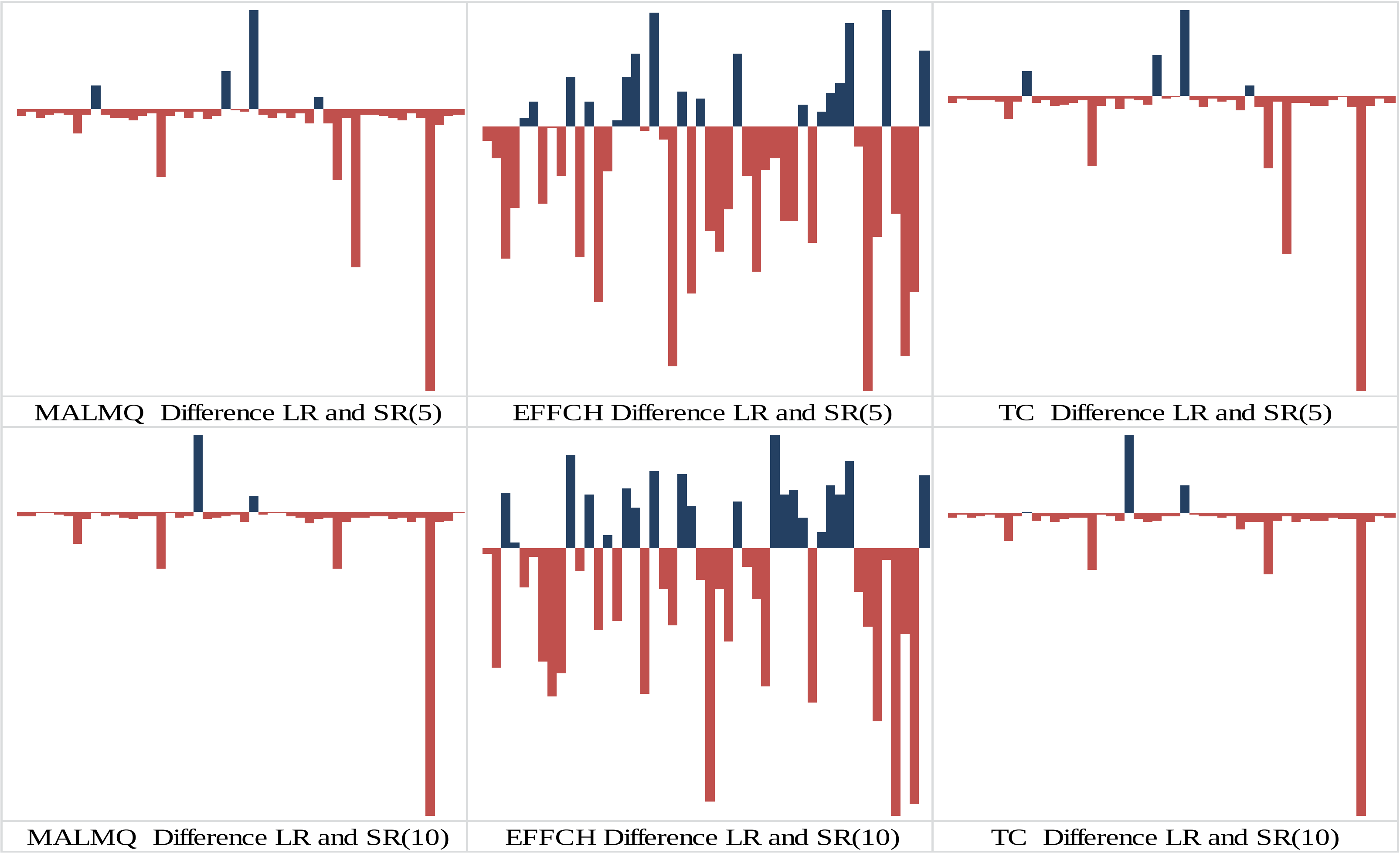

Figure 2. Average differences between long and short-run risk-adjusted measures by year, 1965-2004

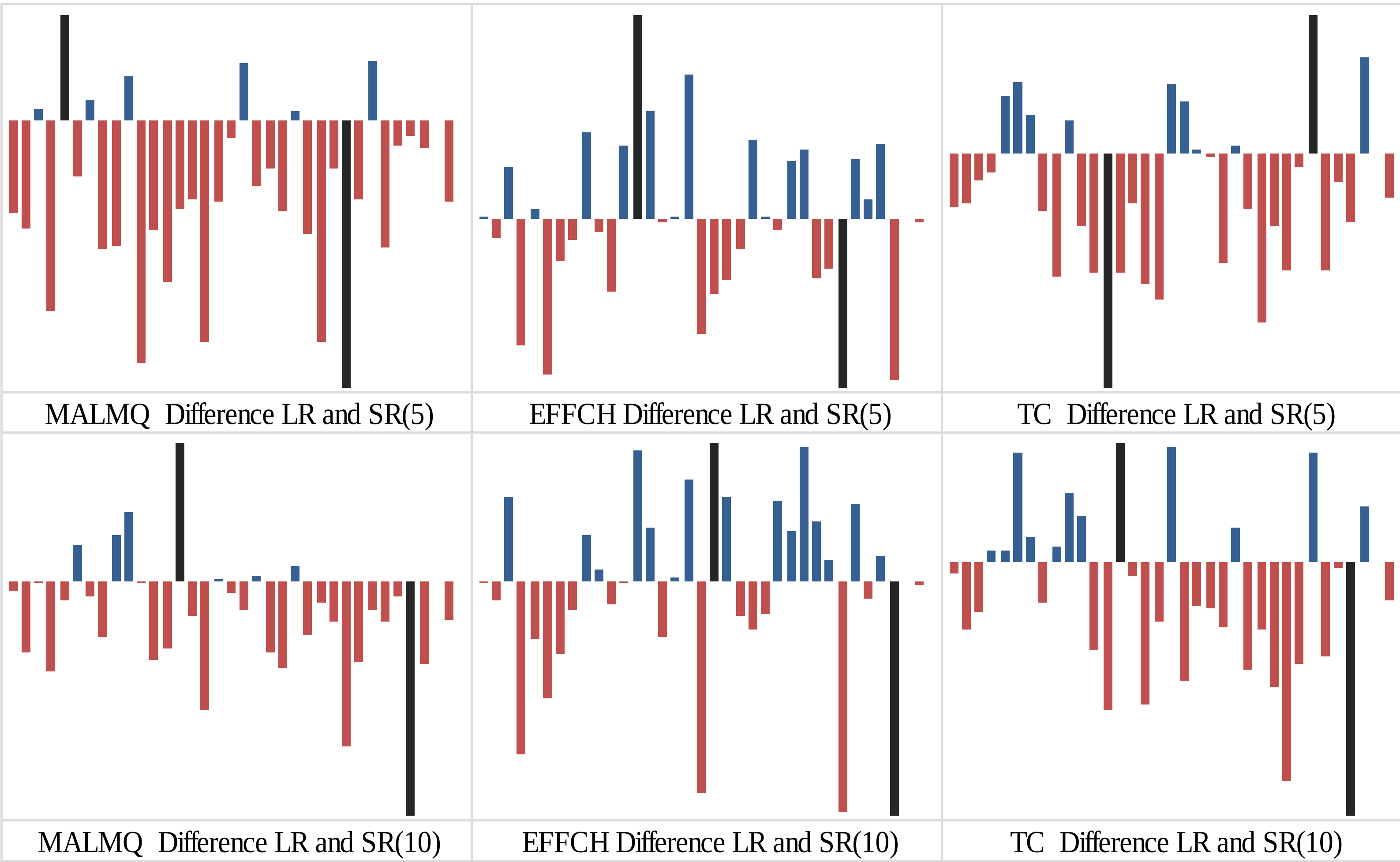

Table 1. Average long and shortrun risk-adjusted TFP measures by state, 1965-2004

	Long Run			Short Run (5 yrs)			Short Run (10 yrs)		
State	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC
AL	1.004	1.000	1.005	1.013	1.000	1.013	1.009	1.000	1.009
AR	1.018	1.002	1.016	1.022	1.003	1.019	1.023	1.005	1.018
AZ	1.004	1.001	1.004	1.015	1.005	1.009	1.006	0.999	1.007
CA	1.009	0.996	1.013	1.017	0.999	1.018	1.011	0.996	1.015
CO	1.006	0.998	1.008	1.010	0.998	1.013	1.008	1.000	1.009
CT	1.010	1.002	1.008	1.017	1.001	1.016	1.015	1.002	1.013
DE	0.976	0.994	0.985	1.010	0.996	1.014	1.011	0.997	1.014
FL	1.009	0.996	1.013	1.016	0.996	1.020	1.016	1.000	1.017
GA	1.015	0.999	1.016	0.983	1.001	0.984	1.017	1.003	1.015
IA	1.010	1.005	1.005	1.016	1.003	1.014	1.014	1.002	1.012
ID	1.009	0.998	1.011	1.019	1.003	1.016	1.012	0.999	1.013
IL	1.009	1.004	1.005	1.020	1.003	1.017	1.016	1.003	1.014
IN	1.012	1.002	1.010	1.028	1.008	1.020	1.020	1.004	1.016
KS	1.004	0.997	1.007	1.014	0.998	1.016	1.008	0.997	1.012
KY	1.010	0.997	1.013	1.014	0.997	1.018	1.015	0.999	1.017
LA	0.922	0.999	0.928	1.016	0.998	1.019	0.984	0.998	0.988
MA	1.015	1.003	1.012	1.025	1.001	1.024	1.015	1.002	1.014
MD	1.007	0.997	1.010	1.010	0.997	1.014	1.013	1.001	1.013
ME	1.002	1.000	1.002	1.014	0.996	1.018	1.006	0.998	1.008
MI	1.017	1.001	1.016	1.021	1.002	1.020	0.932	1.002	0.931
MN	1.009	1.001	1.008	1.022	1.009	1.014	1.017	1.003	1.014
MO	1.007	1.003	1.004	1.016	1.002	1.015	1.014	1.001	1.013
MS	1.011	0.999	1.013	0.959	1.005	0.960	1.017	0.998	1.019
MT	1.006	1.001	1.006	1.007	1.000	1.008	1.010	1.001	1.009

State	Long Run			Short Run (5 yrs)			Short Run (10 yrs)		
	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC
NC	1.008	0.997	1.011	1.012	1.000	1.012	1.018	1.004	1.014
ND	0.940	1.006	0.955	0.801	1.011	0.842	0.922	1.008	0.925
NE	1.009	0.996	1.012	1.017	0.999	1.018	1.012	0.999	1.013
NH	1.013	1.005	1.009	1.025	1.002	1.023	1.015	1.003	1.011
NJ	1.010	1.002	1.009	1.015	1.004	1.012	1.012	1.003	1.010
NM	1.005	0.999	1.007	1.016	1.004	1.013	1.011	1.000	1.011
NV	1.003	0.996	1.007	1.008	0.998	1.012	1.009	1.000	1.009
NY	0.998	1.002	0.996	1.016	1.003	1.014	1.011	0.999	1.013
OH	1.010	1.001	1.009	0.994	1.004	0.996	1.017	0.999	1.018
OK	1.000	1.001	0.999	1.019	1.004	1.013	1.007	1.000	1.008
OR	0.925	1.002	0.927	1.023	1.001	1.021	0.988	1.001	0.992
PA	1.000	0.996	1.005	1.011	1.000	1.011	1.012	1.000	1.012
RI	0.773	1.004	0.782	0.992	1.004	0.987	0.779	1.004	0.784
SC	1.007	1.002	1.006	1.014	1.001	1.014	1.014	1.000	1.014
SD	1.007	1.002	1.005	1.015	1.000	1.015	1.012	1.000	1.011
TN	1.003	0.999	1.003	1.011	0.996	1.015	1.007	0.997	1.011
TX	1.003	0.999	1.004	1.015	1.000	1.016	1.012	1.000	1.012
UT	1.000	0.996	1.005	1.015	1.005	1.011	1.007	0.998	1.010
VA	1.001	0.997	1.004	1.006	1.001	1.006	1.012	1.002	1.010
VT	1.003	1.001	1.001	1.013	0.997	1.017	1.009	1.002	1.007
WA	0.570	0.994	0.580	0.960	0.997	0.963	0.903	1.002	0.902
WI	0.995	0.998	0.998	1.015	1.006	1.010	1.006	1.000	1.007
WV	1.006	1.000	1.006	1.014	1.006	1.010	1.015	1.007	1.009
WY	1.000	0.999	1.001	1.006	0.996	1.011	1.002	0.997	1.005

Table 2 Average long and short-run risk-adjusted TFP measures by year

	Long Run			Short Run (5 yrs)			Short Run (10 yrs)		
Year	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC	MALMQ	EFFCH	TC
1969	0.954	0.993	0.962	1.007	0.986	1.022	0.960	0.981	0.982
1970	0.998	1.003	1.001	1.025	1.016	1.015	1.032	0.996	1.036
1971	0.969	0.960	1.010	0.991	0.960	1.032	0.973	0.961	1.013
1972	0.966	0.987	0.979	0.993	0.993	1.000	0.991	0.991	1.000
1973	1.008	0.992	1.018	1.005	0.977	1.029	1.008	0.976	1.033
1974	1.042	1.016	1.027	1.088	1.051	1.035	1.073	1.048	1.024
1975	0.961	0.961	1.000	0.935	0.959	0.976	0.967	0.972	0.996
1976	1.006	0.993	1.013	1.020	1.036	0.985	0.994	1.015	0.979
1977	0.979	0.996	0.983	0.974	1.007	0.968	0.985	1.010	0.976
1978	0.984	1.003	0.982	1.015	1.009	1.007	1.003	1.008	0.995
1979	0.943	0.996	0.950	0.974	0.973	1.001	0.928	0.988	0.945
1980	1.013	1.071	0.953	1.003	1.074	0.939	0.990	1.069	0.931
1981	0.962	1.006	0.964	1.021	1.026	0.995	0.963	1.011	0.950
1982	0.923	0.943	0.980	0.950	0.924	1.029	0.950	0.944	1.007
1983	1.050	1.066	0.983	1.089	1.011	1.080	1.073	1.042	1.030
1984	1.013	1.025	0.990	1.034	0.996	1.039	0.966	1.015	0.952
1985	0.967	0.984	0.980	0.986	0.985	1.001	0.979	0.994	0.984
1986	0.964	1.004	0.960	1.018	1.004	1.014	1.009	1.004	1.005
1987	0.960	0.983	0.978	0.980	0.943	1.039	0.960	0.964	0.997
1988	1.029	0.991	1.038	1.033	1.023	1.010	1.033	1.031	1.002
1989	1.009	1.008	1.001	0.995	1.029	0.980	1.020	0.983	1.038
1990	1.005	1.011	0.994	1.021	1.028	0.993	1.003	0.995	1.008
1991	1.013	1.023	0.994	1.025	1.032	0.996	1.038	1.030	1.008
1992	0.955	0.975	0.981	0.978	0.953	1.026	0.985	0.984	1.001
1993	1.038	1.026	1.013	1.036	1.025	1.010	1.034	1.032	1.002
1994	0.947	0.976	0.971	0.974	0.980	0.994	0.966	0.961	1.004
1995	1.008	1.028	0.979	1.061	1.012	1.049	1.015	1.019	1.000
1996	0.973	1.008	0.966	0.985	0.989	0.996	0.987	0.983	1.005
1997	0.957	0.997	0.960	1.022	1.013	1.008	1.014	0.986	1.029
1998	0.978	0.992	0.987	0.997	1.006	0.993	1.006	0.988	1.018
1999	1.015	0.981	1.034	1.000	1.027	0.977	1.024	1.024	1.000
2000	1.001	1.001	1.000	1.032	0.985	1.048	1.016	0.987	1.029
2001	0.988	0.985	1.003	0.994	0.980	1.015	0.993	0.988	1.005
2002	0.979	1.043	0.941	0.983	1.023	0.969	1.059	1.039	1.020
2003	0.995	0.965	1.031	1.001	1.009	0.992	1.023	1.009	1.014
2004	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000