Factor effects on Rural Income Concentration in Brazil

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Abstract: In recent studies it was suggest strong rural income dispersion in Brazil, a fact that was also observed in other countries. In this article, aiming at analyzing the rural income dispersion in Brazil, we fit econometric regression models using the Gini index as the dependent variable, technology, and environmental, social and demographic indices as independent variables. The analysis is performed on a regional basis. The statistical approach uses fractional regression and generalized method of moments (GMM). The technological variable crystallizes the production process. This is a data envelopment analysis measure of technical efficiency. The production process uses county data collected from the Brazilian Agricultural Census of 2006. Technology is significant and dominates the relationship in all regions. The other covariates vary in regional intensity.

Key-words: income concentration, agriculture, regression, GMM

1 Introduction

In a recent study exploring the Brazilian Agricultural Census of 2006, [1] suggest a strong concentration of rural income in Brazil. Indeed they report that only 11% of farms ($\approx$500,000) account for 87% of the total value of production. Although this level of rural income concentration is also observed in other countries, for instance, in Europe (2010 Census) the proportion is 14% and in the US (2007 Census) 11%, the identification of factors causing or contributing to rural income dispersion in Brazil, measured by the Gini index, is of interest. One sees in the Brazilian case that the inclusion of the bulk of rural producers excluded from the process of agricultural production may substantially increase agricultural production, rendering more competitive levels of agricultural productivity for the country in the international markets.

There are indications that income concentration results from technology use. Other factors of importance are related to market imperfections. These create difficulties for the diffusion and adoption of technologies – see [2] for further details. They emphasize that market imperfections force the small farmers to sell their products at prices lower than those achieved by the large farms and to buy inputs at higher prices. The market imperfections result from the development conditions where the rural properties are located. Typical examples of market imperfections are generated by segments of the financial market, inputs, product and export markets, infrastructure of sanitation and electricity, access to technical support and information, and education.

Other studies investigating the determinants of rural income dispersion in Brazil are, for instance, [3, 4, 5, 6, 7]. Our contribution to this literature relies on the statistical characterization of the dependence between income dispersion and other contextual variables – technology and the conditions surrounding the farms. Regionally we suggest which components are influential. These results serve the purpose of guiding actions concerning public policies and technical assistance. The dependent variable we use in the analysis is the Gini index, computed for the rural income distribution of each county. The Gini index is a measure of the dispersion of gross income. The variable technology is defined by the variable returns to scale DEA (data envelopment analysis) score of county performance. The output variable is gross rural income and the inputs are expenditures on labor, land and capital. The market imperfection covariates are social, environmental and demographic indicators. We allow for the possibility of the technology being endogenous.

Our discussion proceeds as follows. In Section 2 we describe the production model. Section 3 deals with the methodology. Section 4 presents statistical results and the pertinent analyses. Finally, Section 5 summarizes and concludes the article, pointing out the implications for public policies.

2 Material and Methods

The data for this paper is, in the main, drawn from the Brazilian Agricultural Census of 2006. Production data for DEA computations were aggregated by counties and rank transformed. Farm data were pooled to form averages for each county. A total of 4,961 counties provided valid data for our analysis. This figure represents 89.2% of the total number of counties. The decision-making unit (DMU) for the production analysis is the county. Thus the output variable is the rank of the county mean of gross rural income. Inputs are ranks of county averages of farm expenditures on labor, land and capital. See Table 1 for further details on the definition of inputs and output. The dependent variable is the county Gini index.

Table 1: Description of the production variables

Variable	Components	Unit	Notes
Y (output)	Value of production of cattle, swine, goats, equines, buffaloes, donkeys, mules, sheep, other birds, rabbits, apiculture, sericulture, raniculture, aquaculture, horticulture, flowers, forestry, agro industry, permanent crops, temporary crops, extractive activities	Reais	-
Land	4 percent of land expenses, the rent paid for the land	Reais	-
Labor	Salaries or other forms of compensation paid to family and hired laborers	Reais	-
Capital (technological inputs)	Machinery, improvements in the farm, equipment rental, value of permanent crops, value of animals, value of forests in the establishment, value of seeds, value of salt and fodder, value of medication, fertilizers, manure, pesticides, expenses with fuel, electricity, storage, services provided, raw materials, incubation of eggs and other expenses	Reais	Value of permanent crops, forests, machinery, improvements on the farm, animals and equipment rental were depreciated at a rate of 6 percent a year. Depreciation periods: Machines –15 years, Planted forests – 20 years, Permanent cultures – 15 years, Improvements – 50 years, and Animals – 5 years.

The contextual (independent) variables considered are the DEA technical efficiency and some indicators of rural development. These indicators were suggested by a technical note of the Institute CNA [8]. They are representative of social, demographic and environmental dimensions of county rural development. They were also transformed to ranks and normalized by the maximum. The list follows.

a) Health system performance index. This indicator measures the performance of the Brazilian public health system. It takes into account county access to health services provided, and the quality of hospital and ambulatory care [9].
b) Existence of electricity. Proportion of farms assisted with electric power in the municipal district [10].
c) Basic education development index. This is a quality indicator of pre-college education, measured on a county level [11].
d) Aging rate. Indicator measured at county level. This is one over the ratio population over 60 years/total population [12].
e) Proportion of farms with appropriate garbage destination [12].
f) Water supply. Proportion of farms with water supply furnished by the county water network, wells or farm water springs [10.

Our concern here is the assessment of technology and development indicators on rural income dispersion. As the dispersion measure we use the county Gini index. If x_i is the observed value of a non-negative, not identically zero, variable, the Gini index is defined by $g/2\overline{x}$, where $g=\left(1/n^2\right)\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i-x_j\right|$ and $\overline{x}$ is the sample average of the observations x_i. The index varies in the interval (0,1), with a value close to one indicating concentration.

Consider a production process composed of 4,961 firms (municipal districts or counties). Each municipal district makes use of the input vector (x_1, x_2, x_3) – land, labor, and capital (Table 1) – to produce output level *y*. Let $Y=(y_1, y_2, ..., y_{4,961})$ be the output vector. Let *X* be the $3\times 4,961$ input matrix. The *r*th column of *X* is the vector of inputs used by the municipal district *r* to produce y_r.

The DEA technical efficiency of production $\phi^*(x_o, y_o)$ – performance measure –, for county *o* with production vector (x_o, y_o), output oriented and with variable returns to the scale [13], is given by:

$$\phi^*(x_o, y_o)=\max_{\phi,\lambda}\phi$$

st

i) $Y\lambda\geq\phi y_o$, ii) $X\lambda\leq x_o$ e iii) $\lambda\geq 0, \lambda 1=1$, ϕ free

We emphasize that all production variables are rank transformed and normalized by the maximum. The transformation is usual in nonparametric statistics [14] and reduces the influence of atypical observations in the DEA model. The use of DEA in this study considers the measure of technical efficiency as crystallizing the technological effect on the response variable (income dispersion). More details on DEA models can be seen in [15].

The statistical model is based on the fact that the Gini index is a number in (0,1) for non-constant distributions and DEA may act as an endogenous variable. We combine fractional regression with general method of moments – GMM [16, 17, 18] to produce robust estimates of the parameters specified by the model.

Let $\hat{\theta}_\tau$ be the Gini index of county τ and w_τ the vector of contextual variables including technology. We assume $\hat{\theta}_\tau=G\left(w_\tau\delta\right)+\varepsilon_\tau$, where G (.) is a probability distribution function. The unknown parameter δ is estimated by GMM. This formulation allows for the endogeneity of technology. As a vector of instruments z_τ we use some of the county development indicators. The condition of moments are $E\left(z_\tau\otimes\left[\theta_\tau-G\left(w_\tau\delta\right)\right]\right)=0$, where $\otimes$ denotes direct product. Competitive choices for *G* are the logistic, the standard normal and the inverse of the extreme value distribution. They are given, respectively, by $G\left(u\right)=e^u/(1+e^u)$, $G\left(u\right)=\Phi(u)$, and $G\left(u\right)=1-e^{-e^u}$. The function $\Phi(u)$ is the standard normal.

The Gini index and the technology indicator capture the same market imperfections and, therefore, a strong association is expected between these variables. The basic hypothesis is that high values of technical efficiency are indicative of information and access to technology, and thus available only to farms with a high income level.

3 Results and Discussion

Table 2 reports the averages of the explanatory variables for the Brazilian regions. Development conditions vary markedly regionally and for this reason we opted for regional models. In general, the north and northeast regions show less favorable indicators in all constructs. The same fact is observed with the aggregated indicators of [8] for environmental, social and demographic dimensions. Efficiency is higher in the center-west, followed by southeast and south. The worst relative performances are in the north and northeast.

The mean Gini index per county by region is shown in Table 3. The means differ regionally and are significantly smaller in the south.

3.1 Expected effects on the Gini index of each covariate

The covariates act in an opposite way to the state of market imperfections. Small values of these indicators should imply technical efficiencies clustering to one for high income farms and overall income concentration away from zero. In this context one expects negative contributions for market indicator variables and a positive contribution for technology in the model. Indeed, this pattern was observed in the south. For the other regions we observe a violation of this condition for some attributes, other than technology, due to the different levels of development experienced by each region.

Table 2: Explanatory variables per region

Variable	Region	Mean	Standard error	95% Confidence interval	
Proportion of farms with appropriate garbage destination	North	0.4282	0.0099	0.4088	0.4477
	Northeast	0.2211	0.0041	0.2130	0.2292
	Southeast	0.6520	0.0063	0.6397	0.6643
	South	0.7780	0.0050	0.7682	0.7878
	Center-west	0.5977	0.0135	0.5713	0.6241
Aging rate	North	0.8183	0.0097	0.7993	0.8373
	Northeast	0.6252	0.0053	0.6148	0.6357
	Southeast	0.3931	0.0063	0.3808	0.4054
	South	0.2862	0.0071	0.2724	0.3001
	Center-west	0.6900	0.0168	0.6570	0.7229
Existence of electricity	North	0.1336	0.0063	0.1212	0.1459
	Northeast	0.3525	0.0052	0.3423	0.3627
	Southeast	0.6694	0.0068	0.6560	0.6828
	South	0.7422	0.0062	0.7301	0.7543
	Center-west	0.3566	0.0155	0.3262	0.3870
Basic education development index	North	0.3273	0.0080	0.3117	0.3429
	Northeast	0.2187	0.0037	0.2114	0.2260
	Southeast	0.7479	0.0048	0.7385	0.7574
	South	0.6585	0.0060	0.6467	0.6702
	Center-west	0.5375	0.0116	0.5147	0.5603
Water supply	North	0.4949	0.0153	0.4650	0.5248
	Northeast	0.2879	0.0055	0.2771	0.2987
	Southeast	0.5885	0.0068	0.5752	0.6017
	South	0.6465	0.0067	0.6333	0.6596
	Center-west	0.6307	0.0147	0.6019	0.6594
Health system performance index	North	0.2243	0.0121	0.2006	0.2479
	Northeast	0.3449	0.0050	0.3351	0.3547
	Southeast	0.6269	0.0065	0.6140	0.6397
	South	0.7326	0.0066	0.7197	0.7454
	Center-west	0.3308	0.0127	0.3058	0.3557
Technology (DEA score of performance)	North	0.4545	0.0106	0.4338	0.4753
	Northeast	0.2864	0.0058	0.2750	0.2978
	Southeast	0.6398	0.0067	0.6266	0.6530
	South	0.6356	0.0053	0.6251	0.6461
	Center-west	0.7719	0.0135	0.7454	0.7983
Environmental dimension (aggregated indicator)	North	0.4785	0.0035	0.4717	0.4852
	Northeast	0.4356	0.0020	0.4317	0.4394
	Southeast	0.5433	0.0018	0.5398	0.5468
	South	0.5975	0.0017	0.5942	0.6008
	Center-west	0.5513	0.0045	0.5424	0.5601

Table 2: Explanatory variables per region (continued)

Variable	Region	Mean	Standard error	95% Confidence interval	
Social dimension (aggregated indicator)	North	0.3233	0.0070	0.3096	0.3370
	Northeast	0.2436	0.0024	0.2389	0.2483
	Southeast	0.6702	0.0044	0.6616	0.6788
	South	0.7291	0.0037	0.7218	0.7364
	Center-west	0.5579	0.0083	0.5416	0.5742
Demographic dimension (aggregated indicator)	North	0.4638	0.0053	0.4535	0.4741
	Northeast	0.4003	0.0021	0.3961	0.4045
	Southeast	0.5587	0.0031	0.5527	0.5648
	South	0.5287	0.0031	0.5226	0.5349
	Center-west	0.6373	0.0092	0.6193	0.6554

Table 3: Gini index per region

Region	Mean	Standard error	95% Confidence interval	
North	0.7850	0.0046	0.7760	0.7941
Northeast	0.7991	0.0024	0.7944	0.8037
Southeast	0.8078	0.0023	0.8034	0.8122
South	0.7541	0.0030	0.7483	0.7599
Center-west	0.8390	0.0048	0.8295	0.8484

3.2 Northern region

Table 4 shows the results obtained for the northern region. Hansen specification test is 2.7353 with 2 degrees of freedom (df) and p-value 0.2547.

The Gini index was modeled in the northern region using the covariates: appropriate garbage destination, aging rate, existence of power supply, basic education index, water supply, health index, and technology. The latter is endogenous. The instruments are the rate rural/urban populations, proportion of farms practicing slash-and-burn techniques, average rural family size, appropriate garbage destination, aging rate, existence of power supply, basic education index, water supply, and health index.

All statistically significant variables show the expected signs. The exception is the health indicator. Our view is that public policies regarding the improvement of the health system were not successful in the north. Indeed, the northern region shows the lowest value of the indicator in the country. The regression is dominated by technology, indicating a strong and positive association with income concentration

Table 4: Model results for the northern region

Variable	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
Constant	0.4576	0.1286	3.5600	0.0000	0.2056	0.7096
Garbage destination	-0.0299	0.0850	-0.3500	0.7250	-0.1965	0.1367
Aging rate	0.0159	0.0978	0.1600	0.8710	-0.1758	0.2075
Existence of electricity	-0.2951	0.1595	-1.8500	0.0640	-0.6077	0.0174
Basic education index	-0.2867	0.1077	-2.6600	0.0080	-0.4977	-0.0757
Water supply	0.0722	0.0585	1.2300	0.2180	-0.0426	0.1869
Health index	0.2565	0.0732	3.5100	0.0000	0.1131	0.3999
Technology (DEA score)	0.8527	0.2383	3.5800	0.0000	0.3856	1.3197

3.3 Northeastern region

Table 5 shows the results obtained for the northeastern region. Hansen specification test is 4.9930 with 3df and p-value 0.1723.

The Gini index was modeled in the northeastern region using the covariates: appropriate garbage destination, aging rate, existence of power supply, basic education index, water supply, health index, and technology. The latter is endogenous. The instruments are the rate of rural/urban populations, proportion of farms practicing slash-and-burn techniques, migration index, children vulnerability (proportion of children up to 5 years old with illiterate parents and living in unsuitable sanitary conditions), appropriate garbage destination, aging rate, existence of power supply, basic education index, water supply, and health index.

Only two statistically significant covariates show the correct signs – technology and water supply. Technology dominates the relationship. The unexpected signs are explained by a similar argument to that used in the northern region for the health indicator. The northeastern region has a poor performance in garbage destination and power supply. We believe that in the rural areas of the northeastern region the public investments were not enough to reduce market imperfections.

Table 5: Model results for the northeastern region

Variable	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
Constant	0.3560	0.0330	10.79	0.0000	0.2913	0.4207
Garbage destination	0.2825	0.0657	4.30	0.0000	0.1537	0.4113
Aging rate	0.1697	0.0542	3.13	0.0020	0.0634	0.2760
Existence of electricity	0.1540	0.0366	4.20	0.0000	0.0822	0.2258
Basic education index	0.0183	0.0485	0.38	0.7060	-0.0768	0.1135
Water supply	-0.1026	0.0351	-2.92	0.0030	-0.1714	-0.0337
Health index	0.4351	0.0358	1.21	0.2250	-0.0268	0.1138
Technology (DEA score)	1.0597	0.1544	6.87	0.0000	0.7572	1.3622

3.4 Southeastern region

Table 6 shows the results obtained for the southeastern region. Hansen’s chi-square statistic with 4 df is 2.1745 with p-value 0.7037.

It was necessary to aggregate the indicators in environmental, demographic and social dimensions for model convergence. The environmental variable comprises the complements of the proportion of farms using agrochemicals, degraded areas, practicing slash-and-burn, proportion of farms practicing crop rotation, tillage, planting in contours, practicing minimum tillage, of county areas of forests and agro forestry systems, and of farms with adequate garbage destination. The demographic dimension includes the inverse of the average number of residents per rural household, the aging rate, the dependency ratio (i.e. the complement of the proportion of population considered inactive – 0–14 years and 60 years and older – relative to the potentially active population – 15–59 years old), the inverse ratio between rural and urban population and the migration rate (increase in rural active population between 2000 and 2010). The social dimension combines the literacy rate, the complement of the rural poverty indicator (proportion of rural residents with income below 70 BRL), the county average of monthly per capita nominal income of rural households, proportion of rural residents with income, complement of child vulnerability, existence of electricity, basic education development index, water supply and the health system performance index. Technology and the social indicator were considered endogenous.

In principle, covariates other than technology should be negatively associated with the Gini index. This was observed for demographic and social dimensions. Environmental has a positive sign, implying concentration. We explain this fact observing that the proper environment use may express, under market imperfection conditions, the use of technology and, therefore, may concentrate income.

Table 6: Model results for the Southeast region

Variable	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
Constant	0.5818	0.0665	8.75	0.0000	0.4516	0.7121
Demographic	-0.4555	0.1228	-3.71	0.0000	-0.6961	-0.2148
Environmental	0.6132	0.1303	4.71	0.0000	0.3578	0.8686
Social	-0.7684	0.1244	-6.18	0.0000	-1.0122	-0.5245
Technology (DEA score)	1.1677	0.1410	8.28	0.0000	0.8913	1.4441

3.5 Southern region

Table 7 shows the results obtained for the southern region. Hansen's specification test validates the model and the set of instruments used (1.5043 with 1df; p-value = 0.2200).

The response variable is explained for the southern region by the attributes: proportion of households with adequate garbage destination, aging rate, existence of electricity, basic education development index, water supply, health system performance index, and technology. As instruments we used the ratio between the rural and urban population, the proportion of establishments practicing slash-and-burn, the proportion of households with adequate garbage destination, aging rate, existence of electricity, basic education development index, water supply in rural household and the health system performance index.

In the south, where market imperfections are reduced and the incentive to reduce them further is strong, the signs of the coefficients are in line with this vision, being negative. The exception is the aging rate. A better variable to describe the age effect in all regions would probably be the age of the farm administrator, which is not available in the census data in a continuous format. This is the factor affecting the farm decision process. The proxy we used to capture this effect did not work properly in all regions and is, in fact, reflecting the health condition of the county population.

Table 7: Model results for the South region

Variable	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
Constant	0.0040	0.1734	0.02	0.9820	-0.3359	0.3438
Garbage destination	0.0233	0.0812	0.29	0.7740	-0.1359	0.1825
Aging rate	0.1983	0.0635	3.12	0.0020	0.0738	0.3228
Existence of electricity	-0.5464	0.1097	-4.98	0.0000	-0.7615	-0.3313
Basic education index	-0.2728	0.0668	-4.09	0.0000	-0.4036	-0.1419
Water supply	-0.2002	0.0577	-3.47	0.0010	-0.3134	-0.0871
Health index	-0.1610	0.0636	-2.53	0.0110	-0.2856	-0.0363
Technology (DEA score)	2.3750	0.4001	5.94	0.0000	1.5909	3.1591

3.6 Center-west region

Table 8 shows the statistical results for the center-west region. Hansen's specification test is 4.1436 with 3df and p-value 0.2464.

The Gini index is explained by the environmental aggregate indicator, the aging rate, the existence of rural electricity, basic education development index, water supply, health system performance index, and technology As instruments we used the ratio between the rural and urban population, the average number of residents per rural household, the aging rate, the existence of electricity, the basic education development index, water supply, the health performance index.

All statistically significant covariates have the right signs.

Table 8: Model results for the center-west region

Variable	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
Constant	1.2654	0.2149	5.89	0.0000	0.8441	1.6867
Environmental	-0.7453	0.3577	-2.08	0.0370	-1.4465	-0.0442
Aging rate	-0.0946	0.1024	-0.92	0.3560	-0.2953	0.1061
Existence of electricity	-0.2032	0.0954	-2.13	0.0330	-0.3901	-0.0162
Basic education index	0.0819	0.1225	0.67	0.5040	-0.1581	0.3219
Water supply	-0.1696	0.0824	-2.06	0.0400	-0.3311	-0.0081
Health index	-0.0061	0.1002	-0.06	0.9510	-0.2025	0.1903
Technology (DEA score)	0.4461	0.2210	2.02	0.0430	0.0130	0.8792

4 Conclusions

We studied income concentration in rural areas of Brazil, taking into account the distribution of the county (municipal) Gini index. On average, the income concentration is high (greater than 75%). Significantly, the southern region has the lowest levels of dispersion. Technical efficiency is higher in the center-west region and does not significantly differ between the southern and southeastern regions. The market imperfection conditions also vary from region to region. A relatively poor performance is noticed for the northern and northeastern regions, which have minimum values for all the considered attributes, except for the aging rate and the health system performance index. In the north, the factors existence of electricity and health require further attention of policymakers. In the northeast, the appropriate destination for garbage, basic education and water supply require attention. The power supply and health demand attention in the center-west region. The environmental, social and demographic aggregated indices show the lowest values for the northern and northeastern regions.

The DEA score – the proxy used for technology use – is dominant in the statistical model, explaining income concentration. The technology index is also associated with market imperfections, which are also responsible for income concentration. Thus, the use of public policies to eliminate inequalities in the rural areas must pass through the removal of market imperfections. If this is not achieved, the recently created Brazilian Rural Extension Agency will not be able to respond to the needs of society.

The statistical model based on fractional regression and GMM fitted well for all regions. Depending on the region, it was necessary to consider aggregate attributes for the convergence of the estimators (southeastern and center-west regions). Clearly, the regression relationships show a statistically significant positive association between technology and the Gini index. As expected, the improvements in the surrounding conditions tend to reduce the income dispersion in all regions.

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