The Role of Agriculture on the Recent Brazilian Economic Growth

Humberto F. S. Spolador[1]

E-mail: hspolador@usp.br

Professor of Economics at "Luiz de Queiroz" College of Agriculture - Department of Economics, Administration and Sociology – ESALQ/USP

Av. Pádua Dias, nº 11, P.O. BOX 132, ZIP: 13400-970. Piracicaba-SP-Brazil

Terry L. Roe

E-mail: troe@umn.edu

Professor of Economics at the Department of Applied Economics – University of Minnesota

337h Ruttan Hall, 1994 Buford Avenue. St Paul, MN 55108

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Abstract: This paper investigates the contribution of the Brazilian agriculture to economic growth of the Brazilian economy. It draws upon the Global Trade Analysis Project (GTAP) data base, and other time series data to construct a multi-sector Ramsey model that shows the transition growth of the Brazilian agricultural sector and its effects on growth of the Brazilian economy, with particular emphasis given to the years 1994 – 2010.

Key Words: Agriculture, economic growth, macroeconomics variables

JEL: O10, O11, Q1

1. Introduction

After two decades of stagnation, the Brazilian economy recovered and experienced relatively high rates of economic growth over the period 2000-2010. According to Fraga (2004) the Latin America countries, including Brazil, adopted economic reforms based on fiscal and monetary tightness, economic openness, privatization and deregulation that were mostly implemented by 1995. However, the relatively high rates of growth in real GDP exceeding 3.0% per annum in the early 1990s declined near the end of this decade and returned to rates of growth averaging about 3.7% per annum over the period 2000-10.

Despite the recovery of higher rates of growth, growth performance lies below that of the average rate of the BRICs. This relatively poor performance may be linked to fundamental features and institutional impediments of the economy. One fundamental feature is that Brazil, being a natural resource-rich country, is experiencing a phenomenon known as the "natural resource curse." As shown by Gaitan & Roe (2011), countries with abundant natural resources can grow less rapidly than those countries without when the abundant resource sector faces an inelastic demand for a primary resource (in this case, primary agricultural goods). They show that growth in trade revenues can induce the resource-abundant country to invest relatively less than the country lacking in exhaustible resources" (Gaitan & Roe, 2011, p. 1). Studying constraints to growth, Pinto (2011) fits to Brazilian data a Ramsey growth model with four sectors. The results suggest that the country´s potential to double real income *per capita* from transition growth will require about 79 years (compared to 8 to 15 years for other leading emerging market economies). The key constraints limiting the country's growth, following Rodrik (2006)and Hausman et al (2005)are the low rate of domestic savings (17% of GDP), transportation infrastructure, and the low stock of human capital. The relatively low savings could result from capital market rigidities, as suggested by Rodrik, or from disincentives linked to the natural resource course.

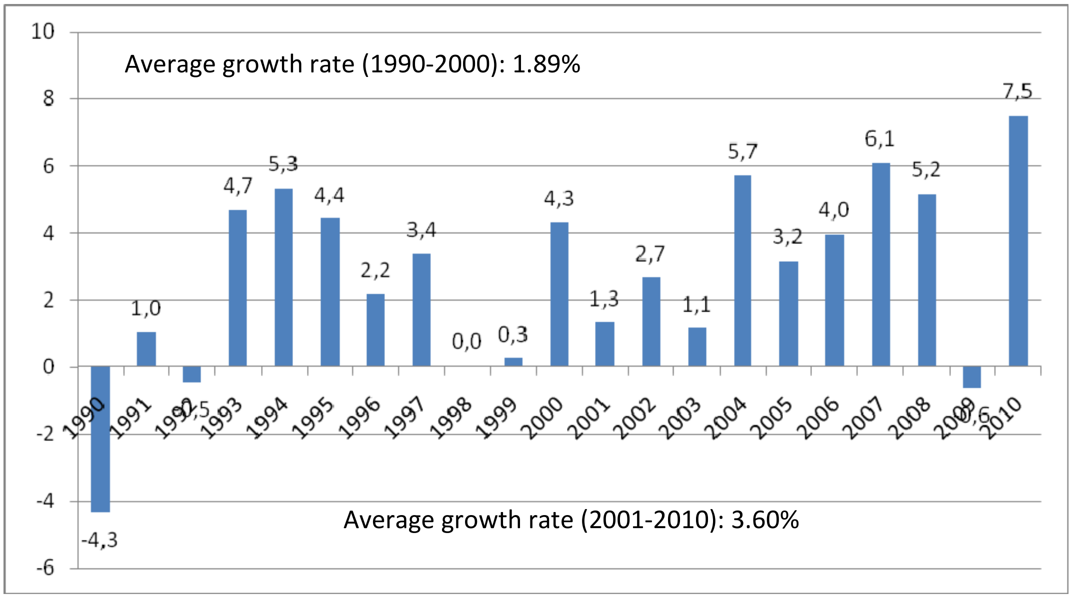

Figure 1. Brazilian real total GDP growth – 1990 to 2010 - % var.
Source: IPEADATA (www.ipeadata.gov.br)

Brazil has experienced an export boom starting in 2003. From 2003 to 2010, the international commodities price increased 185%, and this movement is highly correlated with the Brazilian export expansion (Figure 2), with positive effects on Brazilian GDP growth. The international commodities prices effect on Brazilian exports is particularly important; in the same period, the effective exchange rate became overvalued, in other words[2], the appreciation of the real exchange rate, like a Dutch disease, could serve to dampen the expansion of Brazilian agribusiness exports, but the high level of the international prices have compensated this negative shock on exports.

Frankel (1986) demonstrated that commodity prices are correlated with the monetary policy; high real interest rates depress commodity prices by reducing the demand for storable commodities or, in the short run, by increasing their supply. In another paper, he (2006) argued that high real interest rates encourage speculators to shift out of commodity contracts, while providing incentives to extract commodities in the short run instead of long run. Spolador et al. (2011) demonstrated that this relation is appears weak for Brazilian agriculture. Instead, they find that international prices and world agribusiness exports are more statistically significant to explain the evolution of domestic agricultural prices.

[2] According to the Institute for Applied Economic Research's data, Brazilian real effective exchange rate index, the national currency has been overvalued by about 33.06% from 2003 to 2010.

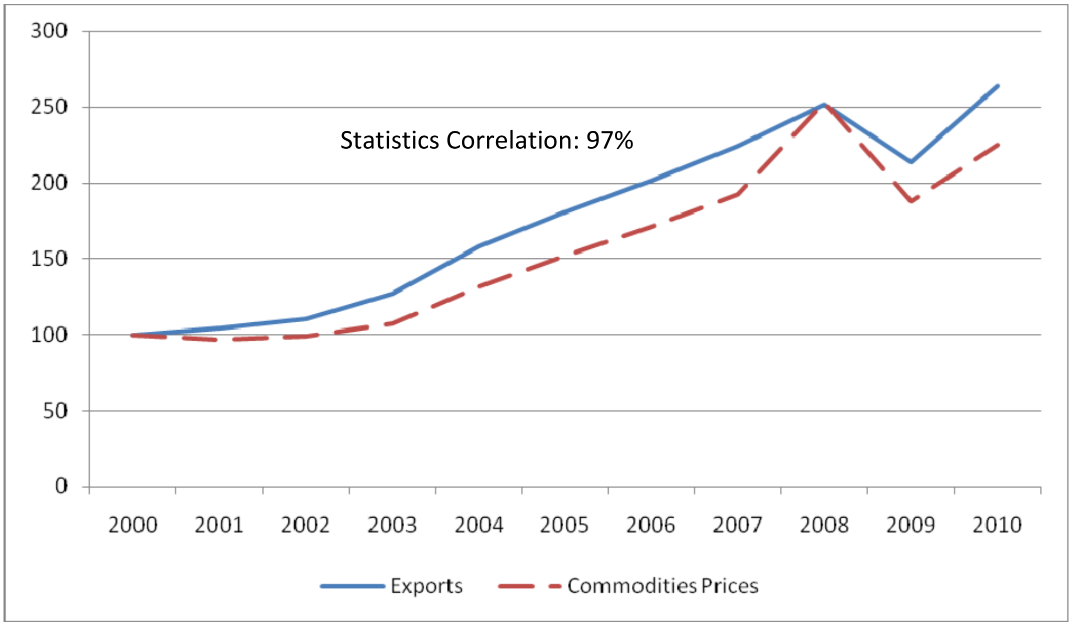

Figure 2. International Commodities Prices and Brazilian Exports – Index (2000 = 100) – 2000 to 2010.
Source: IPEADATA (www.ipeadata.gov.br)

Regarding the structure of the Brazilian economy, the agribusiness sector – including farm inputs, farm output, agro-industries and distribution – comprises a large share of GDP. According to CEPEA (Center for Advanced Studies on Applied Economics) the sector represented around 22% of the Brazilian GDP in 2010. Consequently, agricultural sector shocks tend to produce relevant impacts on the country's economic growth. Figure 3 shows the evolution of the Brazilian agribusiness GDP; the average growth rate on the period 2001-2010 was 3%, approximately, and similar the economy´s growth, despite the years of 2005 and 2009.

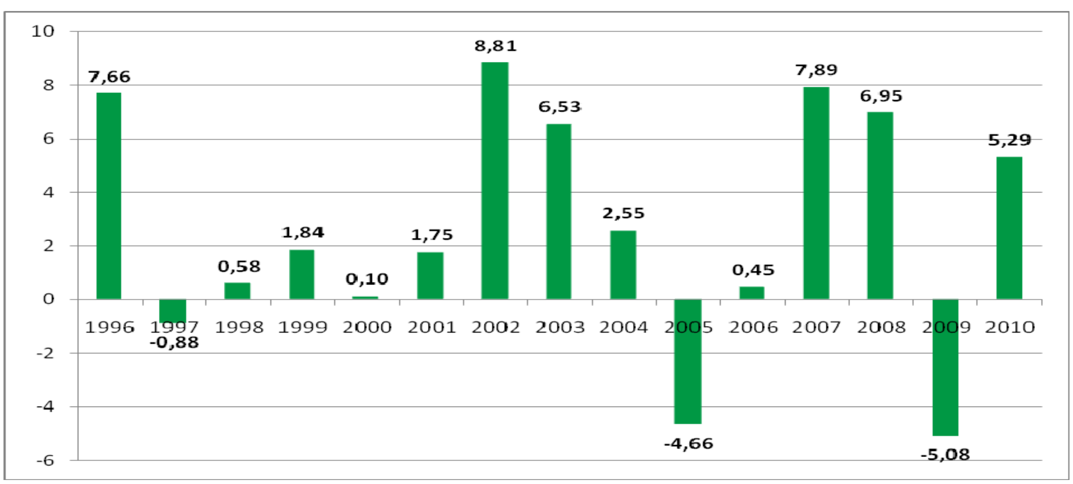

Figure 3. Brazilian agribusiness sector growth (% var.) – 1996-2010.
Source: CEPEA (www.cepea.esalq.usp.br)

The macroeconomic data suggests that at least part of the Brazilian economic growth is sustained by the international market (commodities prices) through the agricultural sector. Alvares-Cuadrado & Poschke (2011) suggest that the "labor push" out of agriculture is due to improvements in agricultural technology that combined with the Engel´s law release resources from agriculture to the rest of the economy as development occurs and per capita incomes grow. Gasques et al. (2011) estimated the Brazilian agricultural GDP growth, over the 1975-2010 period. They conclude that growth in agricultural output has been driven by growth in TFP that was particularly pronounced in the last decade (4.75% aa).

Table 1. Growth Rate of Brazilian Agricultural GDP, Labor, Land, Capital, Inputs and TFP – 1975 to 2008 and sub-periods.

Period	**1975-2010**	**1991-2010**	**2001-2010**	**2006-2010**
Labor	-0.24	-0.43	-0.50	-1.00
Land	0.01	-0.07	-0.29	-0.12
Capital	0.35	0.56	0.26	0.22
Inputs	0.12	0.05	-0.53	-0.89
TFP	3.62	4.60	5.31	4.75
Agricultural GDP Growth	3.74	4.65	4.75	3.81

Source: Gasques et al. (2011)

In the Brazilian case, despite an overvalued national currency and high real interest rates, the economy has grown faster than it did in the late 1990s because, in part, the improvements in agricultural technology (supply shocks) and the higher international commodities prices (demand shocks) has compensated for the constraints identified by Hausmann et al (2005), and the potential negative effects of the exchange rate overvaluation and high interest rates. However, this literature lacks a structural model of economic growth to help verify these hypotheses. So, this paper proposes a dynamic multisector model to analyze the Brazilian economic growth, and the role of agricultural sector on its evolution.

The second section of this paper presents a neoclassical multisector growth model with three sectors and intermediate factors. Its intra and inter-temporal equilibrium is characterized. The third section presents the results and conclusion. The appendix presents the fitting the model data including its validation with time series data.

2. The theorical model

The basic under pinnings of the economic model is based in Roe et al. (2010). The theoretical bases of the growth model date from the works of Ramsey (1928), Cass (1965) and Koopmans (1965) with more recent applications being those of King and Rebelo (1993), Echevarria (2000) and Gollin et al. (2004). The analytical extension here is in the presence of intermediate factors of production, sector specific resource for agriculture and the presence of a non-traded good.

The goods consumed are: manufacturing (Q_m), agriculture (Q_a), and services (Q_s). The resources that the economy employs are workers (L), the stock of which grows at a given exogenous rate (n), capital (K), which grows over time at an endogenous rate, and the stock of land that remains constant (H). Each of the three goods is produced by perfectly competitive firms, which employ primary and intermediate factors of production. The agricultural and manufactured goods are traded on the international markets, while the service goods are sold on the domestic market so that their price is endogenous. Any domestic market surplus or deficit of the traded goods is exported or imported, at the price established in the international market. Households choose at each instant in time to forego some consumption from factor earnings to save. Capital accumulates, less depreciation over time resulting in an increase in the economies level of capital stock. Both labor and capital are employed in the production of the three goods. Land is specific to the agricultural sector, and traded between firms with in the sector only, generating positive rental rates in each period that cause the land rental market to clear. The services of the workforce are not traded internationally, and domestic residents own all the capital stock and land. The households exchange labor, capital and land for wages (w), capital rental (r), and land rent (π).

2.1 The models micro fundamentals

Households are represented by an altruistic and representative consumer who lives a finite number of periods but takes into consideration the welfare and resources of their prospective descendants, as in Ramsey (1928), and receives utility u at each instant of time t from the sequence $\{q_m, q_a, q_s\}_{t\in[0,\infty)}$ expressed as a weighted sum of all future flows of utility defined as:

$$\int_{t\varepsilon[0,\infty)} \frac{u(q_m, q_a, q_s)^{1-\theta} - 1}{1-\theta} e^{(n-\rho)t} dt$$

Where $\rho > 0$ is the inter-temporal discount rate, and $u(q_m, q_a, q_s) = q$ is increasing and strictly concave in q_j, continuous, differentiable and homothetic. The work force grows at positive rate n, determined exogenously.

The household's inter-temporal problem is to choose (q_m, q_a, q_s) to minimize expenditure in each t:

$$\varepsilon = \mathrm{E}(p_m, p_a, p_s) \cdot q \equiv \min_{q_m, q_a, q_s} \{ \sum_{j=q_m, q_a, q_s} p_j q_j \mid q \leq u(q_m, q_a, q_s) \}$$

Where q is the cost of composite consumption of E(.), and (p_m, p_a, p_s) are the representative prices of each good. Following Vinyes & Roe (2010), using Shephard´s lemma, Hicksian demand can be shown to be homogeneous of degree zero in prices p_j.

$$q_j = q^j(p_m, p_a, p_s)\cdot q \qquad j = m, a, s$$

The share of income not spent is accumulated as an asset for future consumption, and capital and loans are considered perfect substitutes. Therefore, the representative household budget constraint is given by:

$$\dot{k} = w + k(r-n) + \pi H - \varepsilon \qquad (1)$$

This formulation of the flow budget constraint presumes that capital markets are complete in the sense that the no arbitrage condition specifying the relationship between the returns to the two assets, capital and land, is satisfied:

$$r = \frac{\pi}{p_H} + \frac{\dot{p}_H}{P_H} = r^k - \delta$$

Where p_H is the price of land, r^k is the capital rental rate paid by firms and δ is the rate of capital depreciation. The Eurler condition obtained from maximizing the discounted present value of utility subject to the budget constraint is:

$$\frac{\dot{\varepsilon}}{\varepsilon} = \frac{1}{\theta}\left[r - \rho + (\theta - 1)\cdot\left(\frac{E_{ps}(p_a, p_s)p_s}{E(p_a, p_s)}\frac{\dot{p}_s}{p_s} + \frac{E_{p_a}(p_a, p_s)p_a}{E(p_a, p_s)}\frac{\dot{p}_a}{p_a}\right)\right]$$

We treat the price of manufactures, p_m, as the *numeraire* price and repress this exogenous variable in the remaining specifications unless needed for clarity. While the home good price p_s is endogenous, the price of the agriculture good relative to the manufactured good evolves exogenously as given by the data which we expressed as a function of time.

Assuming unitary inter-temporal elasticity of substitution ($\theta = 1$) the Euler condition, in terms of effective labor units, A(t)L(t), can be expressed as[3]

$$\frac{\dot{\hat{\varepsilon}}}{\hat{\varepsilon}} = \frac{1}{\theta}[r - \rho - x] \qquad (2)$$

where $A(t)$ is labor augmenting technological change. It is also convenient to express the flow budget constraint in units of effective labor:

$$\dot{\hat{k}} = \hat{w} + \hat{k}(r^k - \delta - x - n) + \hat{\pi}H - \hat{\varepsilon} \qquad (3)$$

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[3] If a steady-state exists, this condition gives the long run rate of return to capital, $r^{ss} = \rho + \theta x = r^{k,ss} - \delta$.

Firms behavior

Roe et al. (2010) assume the firms are competitive and employ neoclassical technology that is homogeneous of degree one in labor and capital, defined as:

$$Y_j \leq \min_{L_j, K_j, Y_{aj}, Y_{mj}, Y_{sj}} \left\{ F^j\left(A(t)L_j, K_j\right), \frac{Y_{aj}}{\sigma_{aj}}, \frac{Y_{mj}}{\sigma_{mj}}, \frac{Y_{sj}}{\sigma_{sj}} \right\} \qquad j = m, s$$

The corresponding cost functions, expressed in terms of effective labor, are given by:

$$\left(C^j\left(\hat{w}, r^k\right) + \sum_{i=a,m,s} \sigma_{ij} \cdot p_i \right) \cdot \hat{y}_j \qquad j = m, s$$

The variable $\hat{y}_j = Y_j \cdot e^{-(x+n)t}$ is the sector j output per effective worker, $l_j = C_w{}^j\left(\hat{w}, r^k\right)\hat{y}_j$ is the share of workers employed in the sector, and $\hat{k}_j = C_r{}^j\left(\hat{w}, r^k\right)\hat{y}_j$ is the amount of capital stock per effective worker employed in sector j. The variables Y_{aj}, Y_{mj}, Y_{sj} denote the amount of the manufacturing, agricultural and services employed as intermediate inputs in producing each good, respectively. The σ_{ij} are the input-output coefficients. They represent the amount of intermediate factor Y_{ij} required to produce one unit of output Y_j. For the agricultural sector, the neoclassical technology is:

$$Y_a \leq \min_{L_a, K_a, Y_{aa}, Y_{ma}, Y_{sa}} \left\{ F^a\left(A(t)L_a, K_a, B(t) \cdot H\right), \frac{Y_{aa}}{\sigma_{aa}}, \frac{Y_{ma}}{\sigma_{ma}}, \frac{Y_{sa}}{\sigma_{sa}} \right\}$$

where B(t) is land augmenting technological change. The value-added by agriculture´s sector specific resource H per unit of effective labor, is:

$$\pi^a\left(p_a, \hat{w}, r^k\right)H \equiv \max_{l_a, \hat{k}_a} \left\{ p_a \cdot f^a\left(l_a, \hat{k}_a, H\right) - \hat{w} \cdot l_a - r^k \hat{k}_a \right\}$$

where $\pi^a(\bullet)$ is the rental rate per unit of land per effective worker required for the equilibrium of the rental market among agricultural producers.

Intra-temporal equilibrium

The intra-temporal equilibrium is characterized by the sequence $\left\{\hat{w}(t), r^k(t), \hat{y}_m(t), \hat{y}_s(t), p_s(t)\right\}_{t\in[0,\infty)}$, given the capital and expenditure pair $\left\{\hat{k}(t), \hat{\varepsilon}(t)\right\}_{t\in[0,\infty)}$ that satisfy the following five market clearing conditions for each t:

1. Perfect market competition for manufacturing and services:

$$C^j\left(\hat{w}, r^k\right) = p_{vj} \qquad j = m, s$$

2. Labor market equilibrium:

$$\sum_{j=m,s} C^j_{\hat{w}}\left(\hat{w}, r^k\right)\cdot \hat{y}_j - \pi^a_{\hat{w}}\left(p_{va}, \hat{w}, r^k\right)\cdot H = 1$$

3. Capital market equilibrium:

$$\sum_{j=m,s} C^j_{r^k}\left(\hat{w}, r^k\right)\cdot \hat{y}_j - \pi^a_{\hat{w}}\left(p_{va}, \hat{w}, r^k\right)\cdot H = \hat{k}$$

4. Home-good (services) market equilibrium:

$$\frac{\partial E(\mathrm{p}_{\mathrm{m}}, p_a, p_s)\cdot \hat{q}}{\partial p_s} = \frac{\lambda_s \hat{\varepsilon}}{p_s} = \hat{y}_s(1-\sigma_{ss}) - \sigma_{sm}\cdot \hat{y}_m - \sigma_{sa}\cdot \hat{y}_a$$

5. and value-added prices:

$$p_{vm} = p_m \cdot (1-\sigma_{mm}) - \sigma_{am}\cdot p_a - \sigma_{sm}\cdot p_s$$

$$p_{va} = p_a \cdot (1-\sigma_{aa}) - \sigma_{ma}\cdot p_m - \sigma_{sa}\cdot p_s$$

$$p_{vs} = p_s \cdot (1-\sigma_{ss}) - \sigma_{as}\cdot p_a - \sigma_{ms}\cdot p_m$$

The model´s system of five intra-temporal equations is solved to express the five endogenous variables $\left(\hat{w}, r^k, \hat{y}_m, \hat{y}_s, p_s\right)$ as a function of the exogenous variables $\left(p_m, p_a, H\right)$ and the other two endogenous variables $\left(\hat{k}, \hat{\varepsilon}\right)$.

From the zero profit and from the factor market clearing conditions we obtain the reduced form factor price and supply functions:

$$\hat{w} = \widetilde{W}(p_s)$$

$$r^k = \widetilde{R}(p_s)$$

and,

$$\hat{y}_j = \tilde{y}^j\left(p_a, p_s, \hat{k}\right) \equiv y^j\left(p_a, p_s, \hat{k}, H\right), \qquad j = m, s$$

Agricultural supply is given by:

$$\frac{\partial \pi\left(p_a, \widetilde{W}(p_s)\right)}{\partial p_a} = y^a\left(p_a, \widetilde{W}(p_s), \widetilde{R}(p_s)\right) H$$

for j = m,s, respectively. Agricultural supply is given by:

$$\hat{y}_a = \pi^a_{pva}\left(p_{va}, \hat{w}, r^k\right)\cdot H = y^a\left(p_a, p_s, W(p_s), R(p_s)\right)\cdot H$$

Inter-temporal equilibrium

The inter-temporal equilibrium consists in deriving the law of motion of the two variables $\hat{k}$ and p_s and indirectly, expenditure $\hat{\varepsilon}$. First, differentiate the home good market clearing condition and use the Euler´s condition (2) to obtain[4]:

$$\tilde{\varepsilon}\left(p_a, p_s, \hat{k}\right)\cdot\left(R(p_s)-\delta-\rho-x\right)=\tilde{\varepsilon}_{ps}\left(p_a, p_s, \hat{k}\right)\dot{p}_s+\tilde{\varepsilon}_{\hat{k}}\left(p_a, p_s, \hat{k}\right)\dot{\hat{k}}+\tilde{\varepsilon}_{pa}\left(p_a, p_s, \hat{k}\right)\dot{p}_a \quad (4)$$

Where $\tilde{\varepsilon}\left(p_a, p_s, \hat{k}\right)$ is a composite expression formed by substituting the supply functions into the intra-temporal home good market clearing condition. Substituting (3) in (4) and solving for $\dot{p}_s$ yields the law of motion for the home good price:

$$\dot{p}_s=\frac{\left[R(p_s)-\delta-\rho-x\right]-\tilde{\varepsilon}_{\hat{k}}\left(p_s, \hat{k}\right)\cdot\dot{\hat{k}}-\tilde{\varepsilon}_{pa}\left(p_a, p_s, \hat{k}\right)\dot{p}_a}{\tilde{\varepsilon}_{ps}\left(p_a, p_s, \hat{k}\right)} \quad (5)$$

The equation for $\dot{\hat{k}}$ is given by substituting the reduced form expressions for $\hat{w}, r^k, \hat{\pi}, and \hat{\varepsilon}$ into the flow budget constraint (3).

Using the method of time elimination Mathematica software is used to solve equations (3) and (5), to obtain the sequence $\left\{\hat{k}(t), \hat{\varepsilon}(t)\right\}_{t\in[0,\infty)}$. After to solve the model for the steady-state, the software backwards from the steady and obtains the values from 1994 to 2034.

Since the price of manufactures p_m is the *numeraire* price, p_a, the agricultural price is a relative price. In our empirical analysis, we calculate from data the evolution of p_a from about 1994 to 2010, and "feed" these data into the differential equations for p_a above to assess the effects of the external terms of trade on Brazilian economy with special emphasis on agriculture.

2.2 The model data and parameter estimation

We fit the empirical model to year 2004 Brazilian data. The main sources were the GTAP (version 7.1), WDI, IPEA (Institute for Applied Economic Research) data that was organized on the Social Accountability Matrix (SAM). From the Brazilian growth accounting exercise we estimate Solow´s residual from which we obtain the Harrod rate of factor productivity growth (x), and the rate of growth of the labor force (n). Following Pinto (2011) the rate of time preference parameter ρ was set to 0.045, this and other parameters are described in table 2.

The sector aggregation in the GTAP data set is in the Appendix A. The data suggest that agriculture is the most capital intensive of all sectors with a capital share in total agriculture

[4] Tilde over the variables denotes a function for which all exogenous variables are suppressed.

value added of 0.584 with labor and land accounting for shares of 0.099 and 0.316 respectively. Manufacture's share for capital and labor in its total value added is 0.529 and 0.471, respectively while the service sector is the most labor intensive with a share of capital in the sector's value added of 0.384 and a capital share of 0.616. Total intermediate input share in the value of gross output is the highest for manufacturing (0.710), followed by agriculture (0.655) and services (0.329). However, within these shares, the service sector is the second largest subcomponent (following own input) of total intermediate input use per unit of gross output value. These structural features of the economy, as Roe et al (2010) show, imply that in the process of capital deepening, Stolper-Samuelson like effects will cause the price of home goods p_s to converge from below to its long-run equilibrium value. This result in a decline in the value added prices faced by the two traded good sectors, albeit adjusted for the change in the external terms of trade, i.e., the rise in the price of the agricultural good relative to the price of the manufactured good.

Table 2. Parameters and initial conditions

δ	ρ	θ	x	n	K(0) in 2004 const USD (millions)
0.04	0.045	1.00	0.016	0.024	229.895

Source: Authors estimates and calculation using GTAP, WDI and IPEA data.

3. Results and Discussion

This section presents results estimated from the theorical model. In contrast to static computable general equilibrium models, contrasting our model's forecast to time series data provides a degree of confidence in interpreting model results. Validation of model forecasts appear in Appendix B. Figures B-1 to B-4 show that the empirical model fits that time series data well which leads us to infer that it captures the essential determinants of the recent Brazilian growth. That said, the most important conclusion from the results is that the bases of Brazilian growth from 2004 to 2034 is unlikely to lead to any dramatic changes in the sectorial composition of the economy.

According to table 3, the GDP per worker grew from 2004 to 2034 at a rate averaging 1.97% per annum, higher than the average of 1980s (decade marked by the economic stagnation) but insufficient to double the GDP per worker over the period, unlike many of the emerging economies in Asia. The growth in GDP is most directly linked to capital deepening, which in turn is caused by the country's relatively low level of initial capital stocks in 2004, the rates of exogenous technological change, and the growth in the labor force all of which provide incentives for households to forgo some consumption to increase their stock of assets over time. Nevertheless, the growth path of income is sufficient to sustain improvement of the income distribution, and to the poverty alleviation.

Table 3. Factor income and expenditure per worker (US$ millions 2004)

Year	GDP	Capital	Wage	Capital rent	Expenditure	Land rental income
1994	4391.85	15188.85	2294.00	2056.24	1344.39	718.06
1999	5080.45	18820.18	2724.44	2314.22	2535.69	852.80
2004	5807.89	22726.38	3158.84	2603.40	3563.26	988.78
2009	6535.59	26579.63	3561.22	2923.52	4077.23	1114.73
2014	7267.38	30311.37	3960.68	3248.19	4584.24	1239.77
2019	8018.19	34012.49	4370.46	3581.72	5096.20	1368.04
2024	8801.22	37761.29	4797.58	3930.05	5622.21	1501.74
2029	9627.61	41626.31	5248.26	4297.99	6171.41	1642.81
2034	10507.27	45667.78	5727.93	4689.90	6751.16	1792.95

Source: Model results

The results suggest that the share of agricultural sector in GDP (table 4) will increase only marginally as the sector capital share in the economy grows, while the its labor share tends to decline only modestly, as the share of the work force in the service sector rise. This result suggests the substitution of capital for labor in agriculture. The sustaining of agriculture's share in GDP is rather unique among emerging economies, most of which have experienced a transition out of agriculture and growth in non-farm production relative to agriculture. It is important to consider that in the SAM (Social Accountability Matrix) used to organized the Brazilian economic data, we computed just the agricultural sector, and not all the agribusiness sector which represents 25% of the Brazilian economy, approximately. As a major agricultural exporter, without any structural change, the international commodities market will be important to the agricultural sector growth and, then, to the Brazilian economic growth. On the other hand, since the financial crisis in 2008 and the recent turmoil on the world economy, the international scenario will unlikely favor Brazilian exports, and specially so for commodities exports. These possible future events are not considered in this empirical analysis.

Table 4. Agriculture value share in GDP and sector shares in total factors

Year	Sector share in GDP	Labor Share	Capital share
1994	0.133558	0.057952	0.119562
1999	0.118266	0.049000	0.106678
2004	0.115552	0.046173	0.103605

2009	0.115571	0.045615	0.102754
2014	0.121132	0.047196	0.106424
2019	0.124859	0.048246	0.108869
2024	0.127512	0.049000	0.110618
2029	0.129357	0.049526	0.111837
2034	0.130626	0.049887	0.112675

Source: Model results

The table 5 confirms that no substantial change in the sectoral composition of the Brazilian economy is likely to occur. The manufacturing sector tends to reduce its share of GDP only marginally while the service sector's share in GDP tends to expand rather modestly. Since the rate of capital deepening as the economy approaches long run equilibrium is approximately 1.6 percent per year, the service sector must compete with the more capital intensive agricultural and manufacturing sector for labor and capital by raising its price so that the home good market clears in response to rising real household income (Table 3). This causes, holding the exogenous evolution of the price of agriculture to the price of manufacturers constant, the value added price of the traded good sectors to decline. In this way, the service sector increases, albeit modestly, is sector share in GDP, and its increase in the share of the economy's work force.

Table 5. Sector value shares in GDP and sectors factor (industry and service) shares in total factors

Year	Sector share in GDP		Labor Share in		Capital share in	
	Industry	Service	Industry	Service	Industry	Service
1994	0.641671	0.221444	0.401943	0.540104	0.504466	0.375970
1999	0.519681	0.361063	0.330181	0.620818	0.437292	0.456028
2004	0.440617	0.443832	0.286666	0.667161	0.391301	0.505094
2009	0.433535	0.451304	0.281588	0.672797	0.385881	0.511365
2014	0.422974	0.456329	0.276075	0.676729	0.378706	0.514870
2019	0.415811	0.459790	0.272351	0.679402	0.373862	0.517270
2024	0.410840	0.462119	0.269796	0.681204	0.370515	0.518867
2029	0.407402	0.463719	0.268038	0.682436	0.368208	0.519955

2034	0.405045	0.464812	0.266838	0.683275	0.366629	0.520696

Source: Model results

To provide more insight into the underlying forces of growth, a growth accounting-like analysis is performed on model results, these are presented in table 6. The results suggest the importance of technical change to the Brazilian agricultural growth. Gasques et al. (2004) emphasized the role of public investments and the rural credit policy on R&D; it is necessary to guarantee the investments on technology to be adopted by the agricultural sector. Using a Vector Autogregressive Analysis (VAR) approach, the authors estimated that the official rural credit system and the public expenditures on R&D represent 26% to 33% approximately of the decomposition of variance of the Brazilian agricultural TFP forecast errors in a period of 10 years. These costs are not accounted for in our framework.

The growth decomposition effects for agriculture in Table 6 show that the increase in agricultural costs due to the rise in labor's wage over time tends to be dominated by the decline in cost due to the decline in the real capital rental rate that serves to lower agriculture's capital cost. This is a Rybczynski like effect associated with Brazilian agriculture being a relatively capital intensive sector. The points in time where the value added price effect is positive is the confluence of the negative effect of the rise in the price of the service good and the positive effect, in selected years, of the rise in the price of the agricultural good relative to the price of manufactures. In later years, the change in this price is negative. Our Hodrick-Prescott trend line of the agricultural to manufacturing price ratio suggests a relatively constant value in later years. These net positive growth effects on agriculture explain the rise in the value added by land as land rental income reported in table 3.

Table 6. Growth in agriculture output and factor contributions

		Contributions to Growth			
Year	Growth in gross output	Value added service price	Wage effect	Interest rate effect	Technical change
1994	0.123106645	0.016653016	-0.06417220	0.130030575	0.040595255
1999	0.020118249	-0.06972267	-0.04995082	0.099196491	0.040595255
2004	0.012668897	-0.05987709	-0.03261375	0.064564494	0.040595255
2009	0.06919295	0.010244596	-0.01746775	0.03582085	0.040595255
2014	0.05160838	-0.00159545	-0.01220917	0.024817752	0.040595255
2019	0.04713487	-0.00197928	-0.00826250	0.016781406	0.040595255
2024	0.045018612	-0.00134018	-0.00558523	0.01134878	0.040595255
2029	0.043616812	-0.00088516	-0.00378299	0.007689715	0.040595255

2034	0.04265483	-0.00059559	-0.00256989	0.00522506	0.040595255

Source: Model results

The manufacturing sector´s growth (table 7), being relatively capital intensive, is strongly influenced by growth in capital stock per worker, and negatively affected by the growth in supply of effective labor. These are Rybczynski effects caused by this sector being relatively capital intensive. Capital deepening causes this sector's marginal value product of labor to rise, requiring, all else constant, for the sector to pull labor from other sectors of the economy. But, growth in labor increases the productivity of capital in the labor intensive sector (services) thus increasing the competition for labor which causes wages to rise and to to negatively affect growth in manufacturing output. These are a typical and well known Rybczynsky-like effects. The negative effect on growth from the decline in manufacturing's value added price is due to the rise in the price of services which are a major component of manufacturing's 0.710 share of the value of intermediate factors in its gross value of output. Over time, as shown by the relative price effect in table 7, manufacturing has benefited only modestly from its terms of trade with agriculture.

Table 7. Growth in industry output and factor contributions

		Contributions to growth				
Year	Growth in gross output	Value added service price	Relative price	Capital Stock	Effective Labor	Agricultural technical change
1994	-0.02131	-0.17455	-0.01319	0.30652	-0.12578	-0.01431
1999	0.03079	-0.16027	0.02683	0.33208	-0.15311	-0.01473
2004	0.05199	-0.11862	0.02613	0.33683	-0.17635	-0.01599
2009	0.03924	-0.06346	-0.00713	0.30546	-0.17953	-0.01608
2014	0.04130	-0.04561	-0.00063	0.28764	-0.18312	-0.01697
2019	0.04119	-0.03138	0.00004	0.27575	-0.18562	-0.01758
2024	0.04097	-0.02144	0.00003	0.26781	-0.18738	-0.01803
2029	0.04083	-0.01463	0.00001	0.26242	-0.18861	-0.01834
2034	0.04074	-0.00999	0.00000	0.25876	-0.18946	-0.01856

Source: Model results

The increase in household and government expenditure (showed on table 3) represents an increase in the demand for service sector services that accompanies the increase in real income. There is a cost push and demand pull component to the rise in service sector price (table8). The pull component arises from increased purchasing power per person caused by capital deepening that most strongly increase the production of export goods and, more indirectly, by TFP effects. This can be seen as a form of the Dutch Disease, i.e., the service sector's competition for resources employed in the traded goods sectors of the economy. The cost push component arises because the service sector is relatively labor intensive, so that wage increase caused by competition for labor from capital intensive sectors contribute to the growth in wages as the competition for labor grows over time, thus increasing service sector production costs relative to other sectors in the economy.

Table 8. Growth in service output and factor contributions

		Contributions to growth				
Year	Growth in gross output	Value added service price	Relative price	Capital Stock	Effective Labor	Agricultural technical change
1994	0.11253	0.15924	0.00634	-0.22811	0.16877	0.00630
1999	0.07085	0.10535	-0.00933	-0.17662	0.14682	0.00463
2004	0.05171	0.06314	-0.00738	-0.14473	0.13662	0.00406
2009	0.04650	0.03292	0.00196	-0.12784	0.13548	0.00397
2014	0.04463	0.02302	0.00017	-0.11734	0.13469	0.00409
2019	0.04332	0.01554	-0.00001	-0.11054	0.13416	0.00416
2024	0.04244	0.01048	-0.00001	-0.10606	0.13380	0.00422
2029	0.04184	0.00709	0.00000	-0.10307	0.13356	0.00425
2034	0.04144	0.00481	0.00000	-0.10105	0.13340	0.00428

Source: Model results

Conclusions and Remarks

Ocampo (2004) demonstrated that the 1990s in Latin America were characterized by market-oriented reforms, which were envisioned to be a first step to modernizing the regions' economies. However, the reforms were not able to produce high rates of economic growth. Zettelmeyer (2006) attributed the low economic growth after the reforms in part to the low TFP (Total Factor Productivity) in the region.

Brazil's recovery was characterized by higher growth rates after 2003 because of two factors: increasing consumer expenditures as consequence of domestic credit expansion (which is also captured by our model) and the improvement of the programs directed to the poverty alleviation and income distribution and secondly, to the growth in commodities exports, (also captured by the model) whose international prices compensated the national currency overvaluation.

Apart from the 1980s and 1990s, the main question about Brazilian economy is not about the economic policies of growth, but to know if the recent growth is sustainable and, to obtain sustainability, if the structure of the economy is likely to experience major changes. The results of this research suggests no structural changes on the long run, i.e., the relative balance between the share of industry, services and agriculture in GDP is unlikely to change in any major way, in contrast to other emerging market economies where the share of agriculture in GDP falls markedly and the share of services rise. Moreover, this structural balance makes sense with the actual macroeconomic scenario and can be attributed to the countries endowment of agricultural resources and the relative capital intensity of the sector. Further, Brazil seems to suffer from a slower rate of capital accumulation than might otherwise be expected. This relatively slow rate of capital deepening might be attributed to fiscal policy which has been expansionist (but not to finance investments on the economy) and, then, the monetary policy needs to be contractionist to sustain monetary stabilization. Consequently the investment share on GDP is low (18.5% approximately). The lack of structural reforms (tax system reforms, improvement on the educational system and so on) likely create conditions causing the country to require more years to double income per worker than many other emerging market economies. Without high investments in R&D, education and infrastructural investments to increase TFP, and a reform of the tax system to help encourage savings and hence capital formation, the Brazilian economy's basic structure will be relatively unchanged, and the agricultural sector will continue to be a strategic sector to spur economic growth. The exogenous rate of technological change estimated for agriculture and used in this analysis is its major source of economic growth. This reaffirms the importance of investments in R&D (not considered in our analysis) to sustain this source of growth and, as an export sector, the need for sound economic policies to maintain the sector's international competitiveness.

The next phase of this research is to study infra-structural investments, paid for as tax transfers from households, that lower the costs of employing intermediate factors of production, particularly services (such as transportation services, energy supplies, telecommunications, legal and institutional structures that tend to increase the price of forming new capital) to better assess whether these features of the economic environment amount to constraints to growth. Agriculture is likely to be particularly sensitive to these services since they account for a relatively large share of intermediate factor costs owing to agriculture as a spatially dependent and relatively capital intensive sector. As the public sector, actually, has insufficient saving to engage in large investments[5], other channels of investment that leverage private sources will also be considered.

[5] According to Rocca (2011) the public administration contributed just with 2.7% of total investments on the Brazilian economy in 2010.

References

CASS, D. *Optimum Growth in an aggregative model of capital accumulation. Review of Economic Studies*. Vol. 32, pp. 233-240, 1965.

CUADRADO-ALVAREZ, F.; POSCHEKE, M. *Structural change out of agriculture: labor push versus labor pull*. American Economic Journal: Macroeconomics 3 (July 2011): 127-158.

ECHEVARRIA, C. *Non-homothetic preferences and growth*. Journal of International Trade & Economic Development. Vol. 9, n.2, pp. 151-171, 2000.

FRAGA, A. *Latin America since the 1990s: Rising from the Sickbed?* Journal of Economic Perspectives, Volume 18, Number 2, Spring 2004, Pages 89–106.

FRANKEL, J. F. *Expectations and the commodity price dynamics: the overshooting model*. American Journal of Agricultural Economics, v. 69, n.2, p.344-348, 1986.

FRANKEL, J. F. *The effect of monetary policy on real commodity price*. Disponível em: http://www.nber.org/books/assetprices/frankel19-26-06.pdf.

GAITAN, B.; ROE, T. International trade, exhaustible-resource abundance and economic growth. Review of Economic Dynamics (2011), doi:10.1016/j.red.2011.08.002

GASQUES, J. G.; BASTOS, E. T.; BACCHI, M. R. P; CONCEIÇÃO, J. C. P. R. *Condicionantes da produtividade da agropecuária brasileira*. Texto para discussão No 1017, IPEA, Brasília, Abril de 2004.

GASQUES, J. G.; BASTOS, E. T.; BACCHI, M. R. P.; VALDES, C. *Nota Técnica: Produtividade e Crescimento da Agricultura Brasileira*. Brazilian Ministery of Agriculture, May 2011.

GOLLIN, D.; PARENTE S. L.; ROBERSON, R. *Farm work, home work and international productivity differences*. Review of Economic Dynamics Control. Vol. 9, pp. 827-850, 2004.

HAUSMANN,R.; RODRIK,D.; VELASCO,A. Growth diagnostics. John Kennedy, School of Government, Harvard University, 2005.

KING, R. G.; REBELO, S. Transitional dynamics and the economic growth in the neoclassical model. American Economic Review. Vol. 83, pp. 908-931, 1993.

KOOPMANS, T. C. *On the concept of optimal economic growth. In the econometric approach to development planning*. Amsterdam: North-Holland, 1965.

OCAMPO, J. A.; *AssociationLatin America's Growth and Equity Frustrations during Structural Reforms*. The Journal of Economic Perspectives, Vol. 18, No. 2 (Spring, 2004), pp. 67-88

PINTO, C. V. *Effects of economy-wide factors on Brazilian economic growth and biofuels production: an inter-temporal general equilibrium analysis*. A dissertation submitted to the Faculty of Graduate School of the University of Minnesota, February 2011.

RAMSEY, F. *A mathematical theory of saving*. Economic Journal. Vol. 38, PP. 543-559, 1928.

ROCCA, C. A. Financiamentos de investimentos no Brasil. Seminário Banco Mundial, São Paulo, Abril de 2011.

RODRIK, D. Goodbye *Washington consensus, hello Washington confusion?* A Review of the World Bank´s Economic Growth in the 1990s: learning from decade of reform. Journal of Economic Literature, Vol. XLIV, 973-987.

ROE, T.; SMITH, R. B. W.; SARACOGLU, D. R. *Multisector Growth Models*. Springer Verlag NY, 2010.

SPOLADOR, H. F. S.; BARROS, G. S. C.; BACCHI, M. R. P. *The determinants of the Brazilian Farm Prices*. AAEA & NAREA (Agricultural & Applied Economics Association – Northeastern Agricultural and Resource Economics Association) Joint Annual Meeting, 2011, Pittsburgh.

VINYES, C.; ROE, T. *Growth diagnostics and a multisector Ramsey model: the case of Brazil*. Agriculture. Economic Development Center, Bulletin Number 10-1, January 2010.

ZETTELMEYER, J. *Growth and reforms in Latin America: a survey of facts and arguments*. IMF Working Paper, September 2006.

Appendix A – Sector aggregation in the GTAP data set

Agriculture	Manufacturing	Services
1. Grains: Rice, wheat, cereal grains	1. Forestry	1. Electricity
	2. Fishing	2. Gas manufacture, distribution
2. Vegetables, fruit and nuts	3. Coal	3. Water
3. Oil seeds	4. Oil	4. Construction
4. Sugar cane, sugar beets	5. Gas	5. Trade
5. Plant-based fibers	6. Minerals	6. Transport
6. Other crops	7. Textiles	7. Sea transport
7. Cattle, sheep, goats, horses	8. Wearing apparel	8. Air transport
8. Animal products	9. Leather products	9. Communication
9. Raw milk	10. Wood products	10. Financial services
10. Wool, silk-worm cocoons	11. Paper products, publishing	11. Insurance
11. Meat: cattle, sheep, goats, horses	12. Petroleum coal products	12. Business services
12. Meat products	13. Chemical, rubber, plastic products	13. Recreation and other services
13. Vegetable oils and fats	14. Mineral products	14. Public administration, defense, health, education
14. Dairy products	15. Ferrous metals	15. Dwellings
15. Processed rice	16. Other metals	
16. Sugar	17. Metal products	
17. Food products	18. Motor vehicles and parts	
18. Beverages and tobacco products	19. Transport quip.	
	20. Electronic equip.	
	21. Machinery and equipment	
	22. Other manufactures	

Appendix B - Validation Results

The models predicted in this work are indicated in figures B-1 to B-4.Basically, the model is fit to data with an initial capital stock estimate corresponding to the year 2004, and the economic model is solved to provide prediction backward to 1994 and forward[6]. The model's forecast of GDP is presented in terms of its value in the base year 2004. The actual GDP and forecast GDP is normalized in the base year 2004 because the subsector definitions of agriculture, manufacturing and service sector GDP do not correspond exactly with the time series data. The main point in this paper is not to fit the exact value of GDPs, but to fit the main sources of their growth.

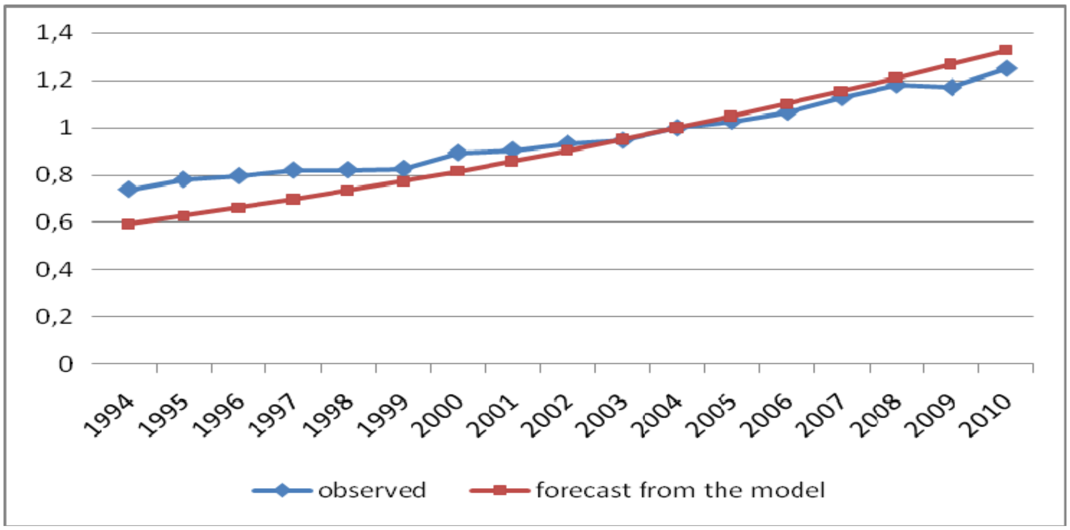

Figure B-1: Brazilian GDP validation (values added relative to 2004)
Source: Model results and IPEADATA (www.ipeadata.gov.br)

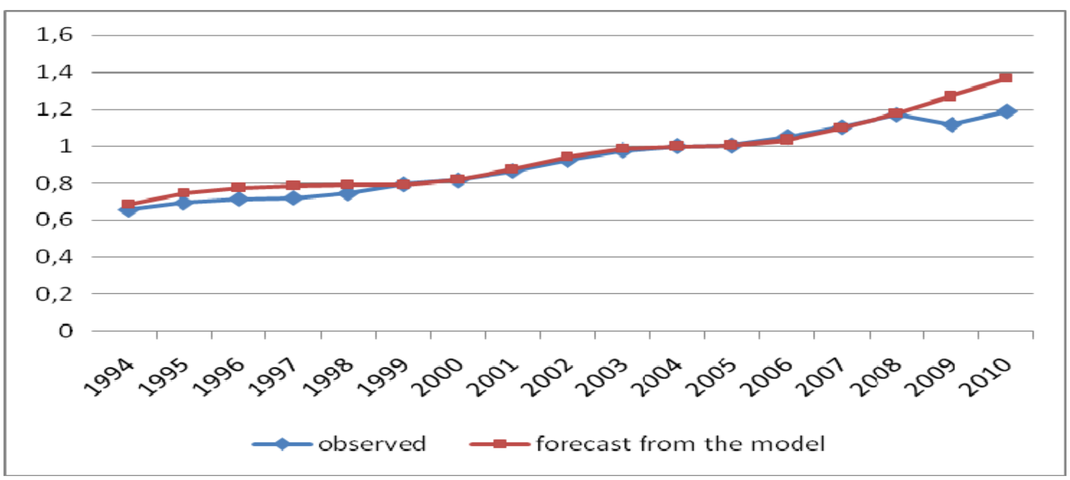

Figure B-2: Brazilian agricultural sector GDP validation (values added relative to 2004)
Source: Model results and IPEADATA (www.ipeadata.gov.br)

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[6] For more details about the Backward integration method see Roe et al. (2010), chapter 9.

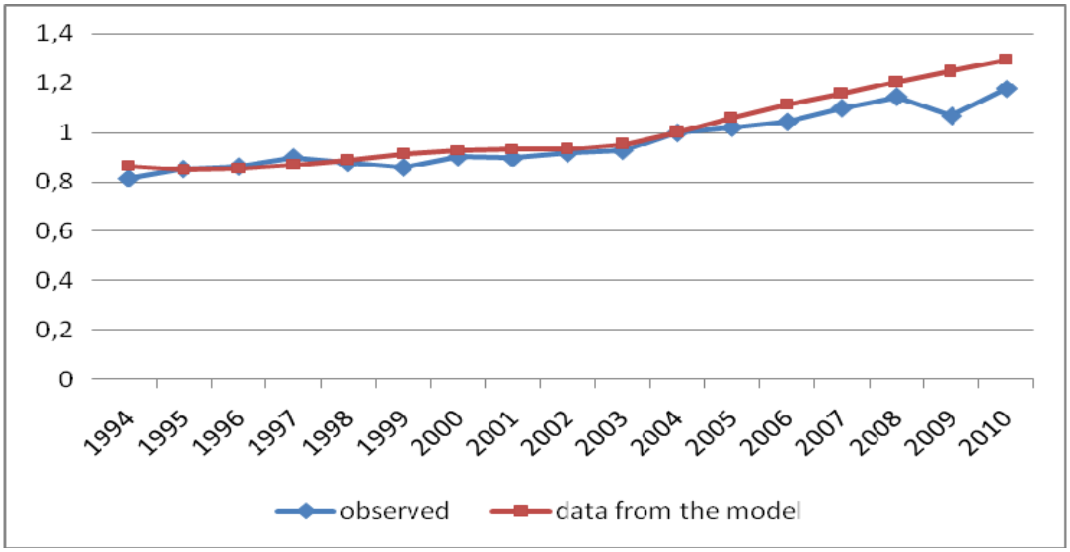

Figure B-3: Brazilian manufacturing sector GDP validation (values added relative to 2004)
Source: Model results and IPEADATA (www.ipeadata.gov.br)

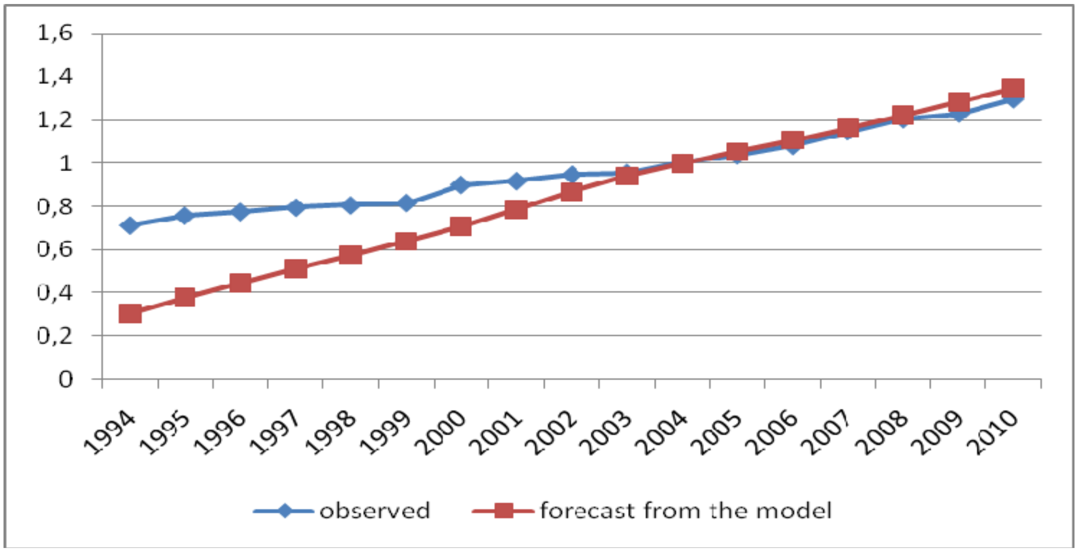

Figure B-4: Brazilian service sector GDP validation (values added relative to 2004)
Source: Model results and IPEADATA (www.ipeadata.gov.br)