TEXTO PARA DISCUSSÃO Nº 418

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Renato Fonseca

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SUMMARY

TRADE LIBERALIZATION AND QUALITY INNOVATION IN BRAZILIAN AUTOS*

Renato Fonseca**

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1 - INTRODUCTION

In recent years the world has witnessed significant political and economic transformation. A notable change has been the increasing importance of international trade in policymakers' minds. The success of the East Asian newly industrialized countries (NICs),[1] the breakdown of the Soviet bloc, and the failure of many developing countries' import substitution industrialization programs, have triggered a worldwide movement toward trade liberalization.

When free trade advocates thought the war was won, some authors pointed out the theoretical and empirical weaknesses of their main arguments in favor of trade liberalization. Rodrik (1992, p.172), for example, concludes that:

> "Until more evidence becomes available, then, a healthy skepticism is in order. In the meantime, if truth-in-advertising were to apply to policy advice, each prescription for trade liberalization would be accompanied with a disclaimer: 'Warning! Trade liberalization cannot be shown to enhance technical efficiency; nor has it been empirically demonstrated to do so."

In Section 3 of his article, Rodrik develops a model that predicts that domestic firms will delay technological innovation in response to trade liberalization. As is common in this kind of model, the cost of innovation decreases with research time. Also, investment in technological innovation represents a fixed cost to the firm.

Rodrik's argument goes as follows: because the cost of innovation is fixed, unit costs will fall as production increases. For a given price, a larger market share implies higher profits and hence greater incentives to innovate. Conversely, a reduction in the firm's market share reduces its expected profit, discouraging innovation. Opening the market to imports decreases domestic firms' market share, and thereby reduces their incentive to innovate.

One should expect domestic firms to lose market share to imports. The size of that loss, however, will depend on the quality and production costs of domestic versus foreign goods. Consumers will move toward imports inasmuch as they offer a better price-quality combination, and delaying innovation may result in a bigger loss of market share. To maintain their market position, firms must speed up innovation. Thus, allowing firms'

[1] The success achieved by these countries is generally credited to an outward-oriented development policy. See Rodrik (1995) for a discussion of different interpretations of the East Asian countries' experience.

innovation strategies to affect their market share may reverse Rodrik's conclusion.[2]

Scherer (1992, p.110) presents several case studies of R&D reactions of U.S. firms threatened by imports. He concludes that:

> "Although U.S. firms have sometimes been caught napping by transnational technological competition, in more cases than not, at least within our sample, the leading domestic incumbents recognized that they had much to lose by failing to respond aggressively. **The most common response was an intensification of product and process developments efforts**" (the boldface is mine).

The industrial organization field is both rich and inconclusive on the effects of market competition on the timing of innovation. There are several models used to explain how market structure affects innovation, but unfortunately, there is no consensus regarding the answer to such questions.[3] However, the conclusion about the effect of a new entrant on a monopolist incumbent is shared by most models.

Reinganum (1989) presents several different theoretical contributions to the innovation timing literature. The theoretical models are classified as *symmetric (the competitors are identical) or asymmetric.* Among the asymmetric models she identifies two families of models. The first, stochastic racing models, argue that a firm that already has a large market share will invest in R&D at a lower rate than a potential entrant [Reinganum (1983)]. Models in the other family, the deterministic auction models, reach the opposite conclusion. According to these models, in a highly concentrated market the incumbent monopoly is more likely to innovate than the challenger [Gilbert and Newberry (1982)].

In both kinds of asymmetric models, new entrants play a crucial role in technical progress by provoking incumbents to invest more in R&D. The main conflict is over who will win the race, the incumbent or the entrant. Symmetric patent race models also reach the same conclusion, that is, starting from a situation of secure monopoly, increasing competition accelerates the R&D process [Scherer (1984, Chapter 2)].

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[2] Here innovation is used in its broadest sense, including the adoption of a process or product that has been just invented, or already adopted, by other firms.

[3] Some economists even claim that there is no important relationship between market structure and innovation, while others claim the causality is inverted, i.e., innovation determines market structure. See Reinganum (1989) for a survey of the literature on the timing of innovation and Cohen and Levin (1989) for a survey of empirical studies on innovation and market structure. See also Scherer and Ross (1990, Chapter 17).

On empirical grounds, there is no less uncertainty. Cohen and Levin (1989) show that empirical work does not resolve the theoretical ambiguity. According to them, although most studies find a positive correlation between concentration and R&D, some find a negative one.

Yet another hypothesis, introduced by Scherer (1984, Chapter 12) and empirically supported by other scholars, has persuaded many theorists. Scherer finds evidence of a nonlinear relationship between market concentration and R&D, an "inverted-U" relationship. Explaining his findings, Scherer (1984, p.246) argues that:

> "(...) some degree of concentration is required before firms eschew price-cutting and grapple for market position through more complex innovative strategies. But in industries with high concentration – such as when the four-firm ratio exceeds 55 percent – pricing interdependence is fully recognized, and group discipline may even be sufficiently strong to permit a 'live and let live' attitude toward technological innovation."

Thus, in a concentrated market, threatening domestic firms with foreign competition would speed up the innovation process rather than slow it.[4] Firms would have to innovate to maintain their market share. Keeping the same innovation pace would be disastrous. Brazilian industry, for example, is highly concentrated, so a gradual liberalization policy would provide both the time and incentive for domestic firms to catch up with the current state of the art.

In justifying such policy, it is important to note that, from firms' point of view, competition generates too much innovation. Acting cooperatively, they would innovate less (at a lower pace) but make higher profits. The country as a whole, however, may not be better off. One reason is that there may be positive externalities related to the innovation activity. Another reason is that a monopoly is typically unable to appropriate the full surplus generated by the introduction of new goods (unless it can price-discriminate perfectly). Then, from a social perspective, firms may innovate too little.

This is a very important question, but it is not the one addressed in this paper. In passing, however, I note that using trade liberalization to force domestic firms to innovate more generates the additional benefits typically associated with free trade. The net result, however, remains ambiguous.

The controversy over the effects of trade liberalization on technological innovation is far from over. Whatever one's view, the need for more

[4] Note that firms do not delay innovation due to an X-inefficiency kind of behavior. Neither do they under-innovate as a pre-commitment to reduce competition. The conclusion that a secure monopoly innovates at a slower pace than a threatened monopoly is based on a profit-maximizing strategy.

empirical studies is clear. In this matter I agree with Rodrik (1992). Before recommending a liberal trade policy, it is imperative that economists provide both theoretical and empirical evidence in favor of the policy.[5]

The main goal of this work is to analyze the effects of trade liberalization on technological innovation. To this end, I carry out a case study of recent Brazilian experience. More specifically, I study the effect of trade liberalization on the quality of Brazilian automobiles. In the next section, I briefly discuss Brazil's recent experience. My methodology is described in Section 3, and my data set in Section 4. The results are shown in Section 5, and are followed by the conclusions.

2 - Brazil's Recent Experience

During most of the postwar period, Brazil, like many other Latin American countries, adopted a largely inward-oriented development strategy of import substitution. Nevertheless, between the end of World War II and 1980, Brazil's industrial output grew at an average annual rate of about 8 percent, while worldwide industrial production rose on average only 5 percent. By 1980 Brazil had the sixth largest manufacturing sector in the capitalist world and was exporting a variety of manufactured goods, with manufactures representing more than half of Brazilian exports [Fritsch and Franco (1992)].

Up until the end of the 1970s, the import-substitution *cum* export-promotion strategy followed by Brazil was quite successful. However, during the 1980s, government protectionism intensified in response to the second oil shock, to the world recession at the beginning of the decade, and to the debt crisis. Moreover, the 1980s saw the conclusion of the process of maturation and concentration of industry.

In an environment like this, one would not be surprised if firms act cooperatively. Thus, one should expect firms to time their innovations in much the same way as would a monopoly facing no threat from imports or new entrants, that is, to innovate relatively slowly.

With the arrival of a new government in 1990, Brazil began liberalizing trade in hopes of providing the correct incentives and conditions for the modernization of its industry. Trade policy was used as an instrument of industrial policy. Its main goal was to increase competition and provide a better environment for innovation, modernization and productivity growth. Most of the nontariff barriers were incorporated into the tariff structure and a

[5] In light of recent developments in the theory of economic growth, this issue becomes even more relevant. According to the new growth theory, innovation is the main engine of growth (see Romer 1994**a** and 1994**b**). Thus, the question of whether trade liberalization stimulates innovation becomes more important than ever.

gradual reduction of tariffs was scheduled over the next four years -- see Table 1 [**Revista Brasileira de Comércio Exterior** (1992, Cap. 6)].

Table 1
New Tariff System -- 1991/94[6]

	1990	1991	1992	1993	1994
Average	32.2	25.3	21.2	17.1	14.2
Median	40.0	20.0	20.0	20.0	20.0
Standard Deviation	19.6	17.4	14.2	10.7	7.9

Source: **Revista Brasileira de Comércio Exterior** (1992, p. 41).

The automobile industry was a main target of the trade liberalization policies of the 1990s. Repeatedly, and even before his inauguration, the President Fernando Collor de Mello expressed his disappointment with the quality of Brazilian cars. During his campaign, he referred to Brazilian-made automobiles as "wagons". Indeed, high on his political agenda was the modernization of the "Brazilian wagons."

It is worth mentioning that the automobile industry has played a vital role in Brazil's economic history. During the "Miracle" period, it grew at an average annual rate of 22 percent while the economy as a whole grew at an average rate of 11.2 percent. The auto industry accounted for more than 10 percent of Brazil's gross industrial product during the 1970s, peaking at 15 percent in 1975. During the 1980s, its share of industrial output fell somewhat, to an average of 9.5 percent. The industry was nevertheless the second largest source of tax revenues, and generated more than a US$1 billion trade surplus, representing, on average, 8 percent of Brazilian exports [Anfavea (1994)].

Since its founding in the late 1950s, the automobile industry has been heavily protected against imports and new entrants. Initially, the government attracted firms by offering fiscal incentives and the promise of a captive market. In the 1970s, the government continued to protect the industry, but replaced the fiscal incentives by export subsidies as a way of pushing it into foreign markets. The protection against imports became stronger, and perhaps necessary, with the balance of payments crises of the 1980s [Shapiro (1994)].

[6] In February 18, 1992, the Minister of Finance moved forward to October 1 those tariff reduction scheduled for 1993, and to July 1, 1993, those scheduled for 1994 (Portaria n. 131, Ministry of Economy, Finance and Planning).

As expected, the combination of a closed and concentrated market slowed the pace of innovation. As noted by Womack, Jones and Ross (1990), by the end of the 1980s, Brazilian auto plants lagged "far behind the world pace in terms of productivity and product quality". They also pointed to the long life of Brazilian models: "fourteen years on average, nearly four times the Japanese standard" [Womack, Jones and Ross (1990, p.269)]. This strategy was, in fact, vindicated by the marketing manager of Volkswagen of Brazil, Mr. Rainer Wolf. In June 1980, in an interview to *Quatro Rodas*, Mr. Wolf said that:

> "Any manufacturer has a big interest in lengthening the life cycle of a product. (...) The longer a car lasts, the bigger the return on the investment required to produce it" (translate by the author).

Thus, because of its important role to the Brazilian economy and its own experience, the automobile industry is the best candidate for this investigation.

The government lifted the ban on imports and scheduled tariff reductions on automobiles and their parts and components (see Table 2). The liberalization schedule, however, was modified four times after its publication in January 1990. On February 18, 1992, the government sped up the whole process. According to the new schedule, the tariff on automobiles would fall to 40 percent in October 1992, and to 35 percent in June 1993 [**Revista Brasileira de Comércio Exterior** (1992, Cap. 6)]. A further change was made on September 14, 1994. As demand was booming, cars were being sold with a significant premium. Then, the government decided to play hard with the automobile industry, and cut the tariff on automobiles to 20 percent.

Table 2
Proposed Tariff Schedule -- January 1990 (in %)

	1990	1991	1992	1993	1994
Automobile	85	60	50	40	35
Parts and Components	40	30	25	20	20

Source: Technical Department of Tariff, Secretariat of Foreign Trade, MICT.

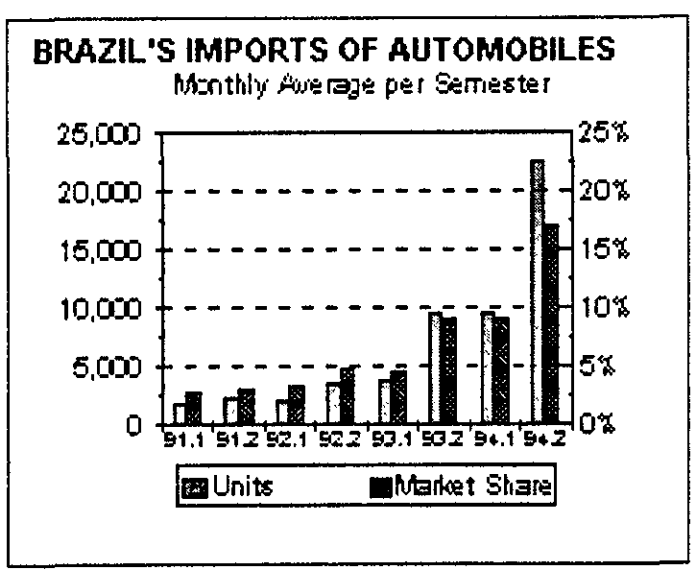
Automobiles imports soared. The trade deficit exploded and the government, afraid of the rapid depletion of the country's international reserves, conceded. In February 1995, the tariff was increased to 32 percent. The next month, the government aborted the whole liberalization policy. Quotas were established on a variety of consumption goods, including automobiles. Moreover, the government further increased the

tariff to 70 percent and reserved the lion's share of the import quotas for domestic automakers. In short, it was a clear return to the policies of the past.

The degree of government commitment is an important factor in the strategy to be followed by domestic firms. If the threat of opening the market to imports is not credible, there will be little effect on firm's behavior. Although the policy was reversed in 1995, it was not until the last quarter of 1994 that the threat was revealed as not credible. Before then, the threat was real, as Figure 1 illustrates. In four years, by the end of 1994, imports passed 30,000 units a month, accounting for 25 percent of the domestic market.

Thus, from 1990 through 1994, we should expect a significant effect on firms innovation strategies. Because these are medium to long-term decisions, their effects should still be felt during 1995 and 1996, at least. Additionally, though controlled, the automobile imports were not banned altogether. Imported cars will still be rolling alongside domestic ones, displaying the latest developments from abroad.

Figure 1



Source: **Carta da Anfavea**, various issues.

To study the effects of liberalization on Brazilian industry, the Industry Confederation (CNI) has conducted annual surveys among the managers of large and medium-sized domestic firms. According to the surveys, quality control programs, rationalization of the production process, and human resource training are the three most-mentioned reactions of domestic firms to trade liberalization. The fourth is investment in technology, followed by

the acquisition of new equipment and the licensing of new technology from abroad. Moreover, according to the same survey, 42 percent said that the liberalization had a positive influence on total investment, against 12 percent who said investment fell [CNI (1994)].

In the automobile industry, investment has risen significantly during the 1990s, although the numbers are not very precise. Also, some new entrants such as the French firm Renault, have already initiated their plans to establish a production line in the country. According to Anfavea (1994, p.40), the level of investment in the vehicle sector, as a whole, jumped from an annual average of US$ 509 thousand in the 1980s to US$ 886 thousand in 1990-93. As reported by the **New York Times** on April 20, 1994, General Motors and Autolatina[7] have both begun US$ 5 billion modernization programs and Fiat is in the middle of a US$ 2 billion modernization. According to Sindipeças (1994, p.46), Autolatina is planning to invest US$ 3.1 billion during 1994-98, General Motors US$ 1.1 billion during 1993-97 and Fiat US$ 800 million from 1992 to 1995.

Exports set a new record in 1994, production is up 52 percent since 1990,[8] and domestic firms have launched an unprecedented number of new models. General Motors, for example, has introduced three totally new models (Omega, Vectra and Corsa) since 1992, compared to only one during the 1970s (Chevette, 1973) and two during the 1980s (Monza, 1983 and Kadett, 1989). Volkswagen and Ford took six years to launch a new model (Apollo in 1990 and Verona in 1989, respectively). But Autolatina has introduced six new models since 1990. Additionally, it completely redesigned the 14-year-old VW Gol and the 11-year-old Ford Escort.

A study by Booz-Allen & Hamilton [Sindipeças (1994)] shows additional evidence of post-liberalization innovation. According to that study, the number of defects per 100 vehicles on the assembly line, fell 50 percent between 1990 and 1993. Also, there was a significant fall (about 40 percent) in the expenses with the warranty per car. Sindipeças (1994, p.43-47) also concludes that trade liberalization was responsible for the rebirth of the "launching process for new products", and for several state-of-the-art components.

[7] Autolatina was the holding company that used to control Ford and Volkswagen of Brazil and Argentina. The venture lasted from 1987 to 1994, a period when the production of passenger cars in Brazil was in the hands of only three firms: Autolatina, Fiat and General Motors. Now, Ford and Volkswagen are competitors again.

[8] It is important to note that the major reason for the increase on production was due the advent of the "popular" car (to be defined shortly). However, total sales in other segments of the car market, rose as well.

3 - METHODOLOGY

To better understand the effects of trade liberalization on the Brazilian automobile industry, it is necessary to construct a measure of quality innovation. Such a measure is built in the following sections. To the best of my knowledge, this is the first attempt to construct a quality change index for Brazilian automobiles.

Innovation is verifiable but is quite difficult to quantify. For example, most of us would agree that a car with electronic fuel injection is superior to one equipped with a carburetor, but, few can define *how* superior it is. Moreover, changes in the quality of a product generally occur in multiple dimensions. That is, several characteristics of the product may change simultaneously, making it harder to quantify the quality. One way to approach this question is to construct a quality index based on the hedonic pricing methodology.

Hedonic Pricing Methodology

The hedonic pricing methodology was developed by Court (1939), and revived by Griliches (1961).[9] Since then, the approach has been used frequently to estimate quality change in automobiles. Among the important contributions are Triplet (1969), Ohta and Griliches (1976 and 1986), Feenstra (1987 and 1988), Gordon (1990) and Raff and Trajtenberg (1995).

The main assumption behind hedonic pricing is the "characteristics approach" to demand theory.[10] According to this approach, goods are defined as bundles of characteristics (qualities), and consumers have preferences over those characteristics. Thus, a consumer will decide not only whether or not to buy an automobile, for example, but which automobile best matches her preferences over the available characteristics.

The real world is full of examples of goods being sold with different added-on components, attributes, sizes, and colors, that is, with different characteristics (qualities), in different varieties. Moreover, the reason that different varieties of a commodity sell at different prices must be due to differences in their sets of characteristics. Therefore it is reasonable to assume that, in equilibrium, there is a well-defined relationship between the price of a commodity and its characteristics.

[9] For more details on the development of the hedonic methodology see, for example, Berndt (1990, Chapter 4).

[10] See, for example, Lancaster (1971).

Based on the assumptions above, it is possible to write the price of variety *i* of a specific commodity at time *t* as a function of a set of qualities *X*, and some disturbance *u*. That is:

$$p_{it} = f_t(x_{1it}, x_{2it}, \ldots, x_{kit}, u_{it}) \quad (1)$$

Additionally, the hedonic approach is based on the assumption that the multitude of models and varieties of a particular commodity can be analyzed in terms of a few characteristics or basic attributes of a commodity. Given the high correlation among some characteristics, this assumption is not as strong as it may seem.

The next problem to be addressed is the definition of the functional form of the relationship represented in equation 1. Here, I will follow previous work and assume a semilogarithmic form, relating the logarithm of the price to the absolute values of the qualities. One advantage of this form is that the coefficients on the *X*'s will represent percentage changes in price due to changes in the related characteristic. In other words, I assume:

$$\log p_{it} = a_0 + a_1 x_{1it} + a_2 x_{2it} + \ldots + u_{it} \quad (2)$$

Equation 2 can be computed for each period for which there are enough observations. An index of quality change can be defined from the estimated equations as follows:

$$q_{ii}^{o} = \frac{P_{i1}}{P_{i0}} \quad \text{where} \quad P_{i0} = f_0(x_{i10}, \ldots), \quad P_{i1} = f_0(x_{i11}, \ldots) \quad (3)$$

That is, the measure of quality change for variety *i* is a ratio between the price predicted, using estimated equation f_0, for the combination of atributes this variety had in period 0 and the price predicted for the combination of characteristics it had in period 1. In other words, the measure gives us the percentage change in price due to changes in characteristics, as predicted by the function f_0. To calculate a quality change measure for the "commodity" (the group of varieties), one can aggregate these *q's* using each variety's market share, for example, as a weight.

Considering that the estimated coefficients will differ among different periods, the general index number problem of changing weights will arise. So, the quality change index will depend on the period chosen as reference. Rewriting equation 3 using the estimated equation f_1 instead of f_0 should produce a different quality change index.

However, for periods not too far apart, characteristics' coefficients may not differ significantly among periods. Here, one may pool the cross section data from the different periods. To account for this, I rewrite equation 2 in the following way:

$$\log p_{it} = \alpha_0 + \sum_{j=1}^{n} \alpha_j x_{jit} + \sum_{s=1}^{S} \beta_s D_s + u_{it} \qquad (4)$$

In specification 4, *i* denotes the commodity's variety, *t* denotes periods (years), *s* denotes years for which there is a specific "time" variable *D*, and X_{ji} represents the set of characteristics of variety *i*. This functional form allows for changes in the intercept over time, but assumes that slopes are constant.

That is, the effect of each characteristic on the commodity's price is assumed constant over the selected years. However, the introduction of time dummies allows the price to change among periods, even when the characteristics remain the same. Note that the time dummies take the value one in their reference period and the value zero in all other periods. Also, the number of such variables in the regression is equal to the number of periods being pooled minus one.

The hedonic pricing methodology has its weaknesses. Many authors have criticized hedonic estimates because of the impossibility of recovering the underlying utility function.[11] However, as Griliches (1990) points out, the aim is not to estimate utility or cost functions per se. Hedonic pricing estimates the intersection of demand and supply curves. It allows us to estimate the implicit, or "missing," prices of characteristics using observed prices of differentiated products and their set of characteristics.

It is also true that we may not be able to recognize the true extent of quality improvement using the hedonic approach. For example, no hedonic measure will detect quality changes that are introduced simultaneously in all goods [Triplett (1969), Rosen (1974) and Trajtenberger (1990, Chapter 1)]. But, as Griliches has reminded us, "half a loaf is better than no bread at all".

[11] Trajtenberger (1990) has proposed an approach based on discrete choice models -- McFadden (1981) and Train (1986) -- that allows one to estimate the parameters of the underlying utility function. Thus, the magnitude of innovation change between two periods can be measured by the increments on consumer surplus. However, this approach requires detailed data on individual consumers level.

Otha and Griliches (1986, p.326-237) summarize the issue as follows:

> "(...) What the hedonic approach attempted was to provide a tool for estimating 'missing' prices, prices of particular bundles not observed in the original or later periods. It did not pretend to dispose of the question of whether various observed differentials are demand or supply determined, how the observed variety of models in the market is generated, and whether the resulting indexes have an unambiguous welfare interpretation. Its goals were modest. It offered the tool of econometrics, with all of its attendant problems, as a help to the solution of the first two issues, the detection of the relevant characteristics of a commodity and the estimation of their marginal market valuation (...).
> To accomplish even such limited goals, one requires much prior information on the commodity in question (econometrics is not a very good tool when wielded blindly), lots of good data, and a detailed analysis of the robustness of one's conclusions relative to the many possible alternative specifications of the model".

4 - THE SAMPLE AND THE VARIABLES

The hedonic analysis reported in Section 5 is based on data for Brazilian passenger cars (excluding station wagons) for the period 1989-1994. For each year of this period an attempt was made to collect price, specification, performance, and market share data for all models for which such data were available. At the end, I have built a data set, disaggregated down to the version level, with 449 observations.[12]

Domestic sales data, by version, was provided by the National Association of Automobile Makers (Anfavea) and the Association of Makers of Parts and Components to Automobiles (Sindipeças). The market share variable was then computed as the ratio between sales of a specific version and the total sales of passengers cars (excluding station wagons) during the year in consideration.

Prices and characteristics were collected from the magazine **Quatro Rodas**, a Brazilian monthly publication specialized in automobiles. The magazine publishes prices and technical information, and carries out its own performance tests. The data set has been constructed based on all issues of the period in consideration.

[12] A model is, in general, offered in different versions. Versions of the same model differs from each other in quality and price. For example, in 1992, the VW Gol (model) was sold in five different versions.

Due to the high inflation during the years considered in this study, I used constant prices. Current price changed too much from one month to the next. Also, to reduce the effect of high inflation on relative prices, I use a four-month average price. That is, for each year in our sample, the current price for the months of May through August was deflated by the wholesale price index (IPA-DI) of their respective month, and then averaged.

The sample is highly representative, though its ratio to total sales falls to 60 percent in 1992 (see Table 3). The lower ratio between sample sales and total sales during the 1990s is due to: **a**) the increased sales of gasoline-based cars relative to ethanol-based cars, **b**) the beginning of the emission control program in 1992; and **c**) imported cars.

Table 3
Ratio of Sample Sales to Total Sales

1988	1989	1990	1991	1992	1993	1994
95%	96%	89%	73%	60%	70%	75%

During the 1980s, following the trend in total sales, most of the cars tested by **Quatro Rodas** used ethanol as fuel. In the 1990s, most used gasoline. Thus, the majority of observations in the data set were gathered in 1990 or later.

The emission control legislation had the same effect, but with greater consequences. Since it affected most performance measures, as well as horsepower, of all models starting in 1992, it practically invalidated the use of any prior test in the construction of the data for 1992 and so on. The task was made still harder by the introduction of imported cars in the domestic market, because the number of domestic cars tested per year decreased significantly, due to "competition" for magazine space with imports.

Most of the versions left out of our sample are ones using ethanol as fuel. Table 4 shows the share of ethanol-based cars in the sample and in total sales. The sample covers most gasoline-based versions. As almost all ethanol-based versions have a gasoline-powered counterpart, we can still argue that the sample is highly representative.

Table 4
Share of Ethanol-Based Cars in New Car Sales

Year	1988	1989	1990	1991	1992	1993	1994
Sample	93%	63%	13%	9%	7%	4%	0.5%
Total	88%	61%	13%	22%	29%	27%	12%

The data set has a large number of characteristics per version. Note that some characteristics are not desired for themselves, but represent other aspects not included in my list of characteristics. For example, the total length or weight of a car are characteristics that are probably not desirable per se, but rather may account for wanted qualities such as comfort and luxury.

I have collected data on the following characteristics: total length (LENG), wheelbase (WBAS), weight (WEIG), and trunk capacity (TRUNK) that account for desirable qualities such as comfort and space. Displacement (DISP), horsepower (HPA), top speed (SPEED), acceleration time from 0 to 100 km/h (ACCE), and braking distance from 80 km/h to 0 (DIST) represent vehicle performance.

Besides the numerical variables, I have dummy variables that take the value of one if the particular version possesses this quality (as standard equipment) and zero if it does not. I defined dummies to represent the following qualities: fuel injection (INJE), power steering (PSTE), front vented disc brake rotor (VENTF), helicoid rear suspension (THELI), anti-lock braking system (ABS), and transverse engine (TRANS).

As a way to compensate for the bias created when comparing big cars with small ones, I have redefined some variables. As heavy cars need a larger distance to stop, I divided DIST by WEIG (DISWEI). A similar rationale applies to horsepower: Cars with big engines tend to have more horsepower than cars with small engines. To normalize the horsepower variable, I divided HPA by DISP (HPACC). Technically, HPACC is a better measure for engine quality, namely, the power per unit of displacement. Other redefined variables are TRULEN (TRUNK divided by LENG) and WBLEN (WBAS divided by LENG).

Some variables account for more than one desired attribute. For example, the variable TRANS, as well as being a proxy for a modern engine, also accounts for internal space and modern design, because a transverse rather than a longitudinal engine allows for more internal room in a given car. The same is true for DISWEI, which may account for both the quality of the brake system and for the vehicle's stability.

Finally, I have also defined dummy control variables. Most models come in different versions. Some versions differ by engine size, horsepower, or other component already included among the regressors, while other versions differ by minor components not accounted for anywhere in the regression model. Therefore, I introduced a "luxury" variable to separate these versions. Those variables L1, L2, and L3, allow me to account for to up to four similar versions of a model. Without these variables, some versions in our sample would differ only by price and market share.

Other control variables are DOOR4 to identify four-door models, CONV to identify convertible versions, POPU to distinguish "popular" cars from the others, and ALCO to identify cars using ethanol as fuel. "Popular" cars have engine sizes under 1.000 cm^3 and have been virtually, exempted from IPI (a federal tax on industrial products), and thus have a significantly lower price for reasons not accounted for by their characteristics. Similarly, ethanol-fueled vehicles have a lower price than their gasoline-fueled counterparts (also due to tax incentives), higher fuel consumption, and, in general, higher horsepower. From 1983 through 1988, cars using ethanol as fuel accounted for more than 95 percent of new car sales, but during the 1990s, their share fell to about 20 percent (see Table 4).

Figures 2a-l present a series of graphs illustrating the evolution of Brazilian passenger car characteristics from 1988 to 1994. The dummy variable graphs show the share of cars sold with the respective "quality" as standard equipment. For the numerical variables, the graphs show the average, weighted by the version's share of sale.

Figures 2a-l offer evidence of the quality evolution of Brazilian autos during the 1990s. Looking at the behavior over time of these characteristics for the whole sample, suggests that quality did not change much, and may even have fallen. However, once we account for the phenomenon of "popular" cars, the quality improvement becomes evident. Excluding the bottom segment of Brazilian cars accentuates the observed quality upgrading during recent years. However, as can be seen, even in this bottom segment quality seems to be improving (this issue will be discussed again in the next section).

Additionally, it is important to note that rear disc brakes (with solid and, later with vented rotors) came as standard equipment in about 10 percent of the automobiles sold in 1994, compared to 2 percent in 1990.[13] Also, anti-lock braking systems and 16-valve engine made their debut in Brazilian passenger cars in 1993.

The behavior of the variables HPACC and TRANS need some explanation. The fall of HPACC (see Figure 2a) from 1988 to 1990 is largely a result of the substitution of gasoline- for ethanol-based cars during those years (see Table 4). As already mentioned, ethanol-based engines had, generally, more horsepower than their gasoline counterparts. In 1992 the average HPACC fell again, now due to the introduction of the emission control program. Subsequently, the use of electronic fuel injection rose sharply (see Figure 2k), and its positive effect on horsepower made HPACC jump substantially.

[13] The 1994 figure rises to 25 percent when "popular" cars are excluded from the sample.

The fact that 100 percent of "popular" cars had a transverse engine (TRANS, Figure 2i) in 1990 and 1991 is because the only "popular" car available in those years was the Fiat Uno Mille. Fiat introduced the transverse engine in Brazil in 1976, and its whole line uses this kind of engine.

5 - THE REGRESSION RESULTS

Sometimes a manufacturer may set the "wrong price," given the quality of its vehicle. Not accounting such deviations from the "right price" may bias our conclusions. To minimize the mistakes and idiosyncrasies of manufacturers' pricing policies, I weighted the data with the market share of each version.[14]

The procedure used to estimate the hedonic equations was weighted least squares, with market share as the weight. Weighted data were computed by multiplying the original data by the square root of the weights. The estimated coefficients are nothing more than ordinary least squares coefficients for the regression with weights. However, the constant is no longer a constant, but is instead the square root of the weights.

Multicollinearity is a sure problem in this kind of study. Luxury models have higher qualities, and so possess most of the quality characteristics. Thus, one should expect a high correlation among the variables in the sample. This problem was approached in the following way. Those variables with very high correlation and representative of the same desired characteristics were all, but one, excluded from the regression. I used the variable LENG, but dropped the variables WEIG, WBAS and WBLENG from the model. Also, SPEED, ACCE, HPA, CC, and HPACC represent the same attribute, performance. Thus, the introduction of more than one o f these variables would harm the model due to near-multicollinearity, without adding much to its explanatory power.

Variables representing different attributes were kept, despite the problem of near-multicollinearity. Of course, it would be nice if the explanatory variables of our model were linearly independent. However, to exclude variables with this goal in mind is to negate the model fundamentals. Excluding those variables may create specification problems, since one may be omitting a relevant variable. Additionally, it is worth recalling that the least squares estimator will remain the best unbiased estimator of the parameters. As Greene (1993, p.270) points out, the problem with multicollinearity is that "best" is not very good.

[14] Graphing the squared residuals (of a non-weighted regression) against market share showed evidence that observations with small market share tend to produce estimates with a higher deviation from the true price.

Heteroskedasticity was another problem I faced during the estimation. In the presence of heteroskedasticity, least squares estimators are still unbiased and consistent. However, they are no longer efficient, i.e., they are no longer the best linear unbiased estimators. Additionally, the estimated for the standard errors of least squares are biased, so the usual confidence intervals and test statistics are incorrect.

To test for heteroskedasticity I applied White's General test [Greene (1993, p.323-393)]. After regressing the squared residuals of the regression against all explanatory variables I constructed an *F*-statistic of 6.596, which, compared to $F_{0.99}(18,430) = 1.96$, gives us evidence of heteroskedasticity.

Here again, in most of the cases, the proposed remedy may do more harm than good [Greene (1993, p.407-408)]. My approach is to stick with the original estimators but correct for the estimated variance of the least squares estimator. This enables me to still do inference statistics. To this end, I use White's method [Greene (1993, p.391)].

The variables used in the regressions are described on Table 5. Table 6 displays the estimated parameters for four different specifications, based on the whole period, that is, pooling the observations for the six years (1989-94). Here I am assuming that the coefficients are stable during the six-year period. Equations 1 and 2 differ only by the inclusion of the variable ABS in the first. As we see the estimates generated by both equations are practically the same. In equation 3, I substituted HPACC for DISP and included the variable THELI. Equation 4 uses only dummies as explanatory variables, and as expected, it predicts a larger improvement in quality.

Testing the stability of the parameters, using the Chow test [Greene (1993, p.211-212)], the result was positive for equations 3 and 4, but, equations 1 and 2, did not pass the test. To run the test I split the period into two sub-periods: 1989-91 and 1992-94. For equation 2 (and so, for equation 1) the calculated *F*-statistic was 2.25. The 1-percent critical value, with 14 and 421 degrees of freedom, from the *F* table is 2.11, so we reject the hypothesis of stability.[15] Equation 3 yields a *F*-statistic of $F = 1.99$, and equation 4, 2.14. Comparing them with $F_{0.99}(15,419) = 2.04$ and $F_{0.99}(13,423) = 2.18$, respectively, we cannot reject the hypothesis that the coefficients are the same. Table 7 reports the estimates for equations 1 and 3, based on two three-year periods. Comparing the equations, note that, despite probable multicollinearity, the coefficients seem to be quite stable.

[15] The ABS system was introduced in 1993. To run the stability test I drop the ABS dummy. Thus, equation 1 becomes identical to equation 2.

tabela 5

List of Variables

Variable Name	Technical Specification	Unit
Control Variables		
ALCO	Fuel: Ethanol	dummy
POPU	"Popular" Car	dummy
L1	Luxury level 1	dummy
L2	Luxury level 2	dummy
L3	Luxury level 3	dummy
CONV	Convertible	dummy
DOOR4	Four doors	dummy
Quality Variables		
DISP	Displacement	
HPACC	Horse Power/Displacement	
LENG	Total Length	
INJE	Fuel Injection	
PSTE	Power Steering	
TRANS	Transverse Engine	
THELI	Helicoidal Rear Suspension	
VENTF	Front Vented Brake	
DISWEI	Brake Distance/Weight	
ABS	Anti-lock Brake System	

Table 6
Pooled Regression Results: 1989-1994

Equation:	1	(0.27)	2	(0.40)
Dep. Variable:	LPRICIP		LPRICIP	
Number of Obs.:	449		449	
Adj. R-squared:	.920		.918	
SSR:	6.511		6.654	
Explanatory Variables:	**Coefficients (t-stat.)**		**Coefficients (t-stat.)**	
C	7.02**		7.041**	
	(19.32)		(19.26)	
ALCO	-0.044		-0.045	
	(-1.79)		(-1.82)	
POPU	-0.334**		-0.334**	
	(-11.86)		(-11.69)	
L1	0.085**		0.087**	
	(4.26)		(4.31)	
L2	0.219**		0.216**	
	(6.81)		(6.47)	
L3	0.166*		0.163*	
	(2.42)		(2.41)	
CONV	0.532**		0.527**	
	(5.99)		(5.86)	
DOOR4	-0.004		-0.003	
	(-0.19)		(-0.13)	
DISP	-		-	
HPACC	8.756**		8.859**	
	(5.51)		(5.55)	
LENG	0.0014*		0.0014*	
	(2.42)		(2.36)	
INJE	-		-	
PSTE	0.311**		0.319**	
	(10.3)		(10.2)	
TRANS	0.087**		0.085**	
	(4.23)		(4.12)	
THELI	-		-	
VENTF	0.214**		0.214**	
	(7.14)		(7.19)	
DISWEI	-19.08**		-19.59**	
	(-4.46)		(-4.55)	
ABS	0.255**		-	
	(4.79)			
Y90	-0.045		-0.045	
	(-1.68)		(-1.66)	
Y91	-0.134**		-0.133**	
	(-4.08)		(-4.06)	
Y92	0.085**		0.086*	
	(2.46)		(2.45)	
Y93	0.163**		0.166**	
	(5.44)		(5.45)	
Y94	0.01		0.015	

cont.

3	4
LPRICIP	LPRICIP
449	449
.914	.894
6.952	8.596
Coefficients (t-stat.)	**Coefficients (t-stat.)**
7.65**	7.27**
(20.8)	(286)
-0.014	0.009
(-0.58)	(.354)
-0.274**	-.329**
(-8.99)	(-9.74)
0.089**	0.122**
(4.50)	(5.24)
0.171**	0.203**
(4.92)	(5.51)
0.20**	0.179**
(3.04)	(3.59)
0.531**	0.57**
(5.76)	(5.27)
0.0003	0.082**
(0.01)	(3.79)
.0001*	-
(2.19)	
-	-
.0006	-
(0.94)	
-	0.108**
	(3.03)
0.361**	0.485**
(11.3)	(17.0)
0.126**	0.064**
(5.33)	(2.69)
0.067**	0.066**
(3.02)	(2.88)
0.182**	0.30**
(5.53)	(9.04)
-21.48**	-
(4.68)	
-	0.278**
	(2.89)
-0.046	-0.046
(-1.62)	(-1.48)
-0.131**	-0.13**
(-3.83)	(-3.36)
0.089*	0.028
(2.47)	(0.76)
0.185**	0.127**
(6.0)	(4.02)
0.032	-0.022
(0.90)	(-0.56)

* Significant at 95 percent. ** Significant at 99 percent. t-statistics are in parentheses.

Table 7
Pooled Regression Results: 1989/91 - 1992/94

Equation:	1	1	3	3
Dep. Variable:	LPRICIP	LPRICIP	LPRICIP	LPRICIP
Pooling Period:	1989-91	1992-94	1989-91	1992-1994
Number of Obs.:	258	191	258	191
Adj. R-squared:	.87	.97	.86	.96
SSR:	4.57	1.48	4.95	1.54
Explanatory Variables:	**Coefficients (t-stat.)**	**Coefficients (t-stat.)**	**Coefficients (t-stat.)**	**Coefficients (t-stat.)**
C	6.557**	7.546**	7.40**	7.68**
	(15.5)	(14.9)	(16.6)	(10.9)
ALCO	-0.059*	-0.015	-0.021	0.0003
	(-2.12)	(-0.57)	(-0.74)	(0.01)
POPU	-0.296**	-0.37**	-0.246**	-0.224*
	(-11.0)	(-7.01)	(-7.84)	(-2.33)
L1	0.073*	0.121**	0.053	0.135**
	(2.45)	(4.72)	(1.70)	(5.12)
L2	0.17**	0.198**	0.165**	0.204**
	(3.35)	(6.36)	(2.99)	(4.99)
L3	0.11	.235**	0.199**	0.252**
	(1.81)	(4.07)	(2.62)	(3.23)
CONV	0.632**	0.451**	0.643**	0.441**
	(5.54)	(3.50)	(6.06)	(3.43)
DOOR4	0.04	-0.024	-0.009	-0.022
	(1.42)	(-0.70)	(-0.03)	(-0.59)
DISP	-	-	0.0001*	0.0002
			(2.31)	(1.51)
HPACC	13.67**	4.69	-	-
	(6.04)	(1.67)		
LENG	0.0018**	0.0011	0.001	0.0002
	(2.74)	(1.29)	(1.40)	(0.23)
PSTE	0.354**	0.318**	0.345**	0.321**
	(7.25)	(6.46)	(5.93)	(5.52)
TRANS	0.116**	0.052	0.182**	0.035
	(4.35)	(1.48)	(5.81)	(0.94)
THELI	-	-	0.118**	-0.015
			(4.29)	(-0.41)
VENTF	0.219**	0.177**	0.147**	0.194**
	(6.90)	(3.56)	(3.69)	(3.70)
DISWEI	-17.51**	-21.1**	-20.9**	-19.9**
	(-3.40)	(-3.78)	(-3.55)	(-2.68)
ABS	-	0.262**	-	-
		(4.79)		
Y90	-0.049	-	-0.053	-
	(-1.85)		(-1.86)	
Y91	-0.151**	-	-0.144**	-
	(-4.80)		(-3.97)	
Y93	-	0.088*	-	0.94*
		(2.21)		(2.38)
Y94	-	-0.050	-	-0.027
		(-1.00)		(-0.58)

* Significant at 95 percent. ** Significant at 99 percent. t-statistics are in parentheses.

The automobile market has gone through significant changes during the 1990s, particularly after 1992. The main changes were: **a**) the re-emergence of gasoline-fueled vehicles; **b**) trade liberalization and the large number of imported cars and components that entered the country; **c**) the birth of a new segment, "popular" cars; and **d**) the emission control policy of 1992. It is expected that these changes had some effect on the conditions underlying the supply and demand for automobiles and for their characteristics. Thus, to construct the quality index, I rely on the estimates using three years of pooled data (Table 7).

The variables HPACC, TRANS, and THELI show suggestive differences between the coefficients and deserve some comment. HPACC, as shown in Figure 2a, did not follow a smooth path. It was heavily influenced by factors **a** and **d**, listed above. Additionally, electronic fuel injection (INJE) became quite popular after 1992 (see Figure 2k). Its production cost almost certainly fell during the period. Thus, it may explain the reduction in INJE's estimated coefficient, and in HPACC's coefficient as well.

The use of helicoid rear suspension (THELI) has been quite stable in Brazilian automobiles throughout the period, with the exception of the "popular" segment (see Figure 2j). However, an important change occurred among cars using this kind of suspension. In 1990, 26 percent of cars with helicoid rear suspension had an independent suspension. From 1991 to 1994 this figure rose and then fall sharply: from 40 to 25 to 5 to 2 percent. By the end of the period, semi-independent rear suspension dominated the market. Although we cannot disregard the effects of multicollinearity, this change may help explain the instability of the coefficient on THELI.

Figure 2i illustrates the evolution of the share of cars sold with a transverse engine (TRANS). During the early 1990s, the share of new "popular" cars with a transverse engine was biased upward profoundly. However, it is not clear how this could cause the TRANS coefficient to behave as it does. Additionally, as mentioned before, TRANS may be capturing two different desired qualities.

The quality index, however, appears to be virtually immune to these changes in the coefficients. I have calculated indexes based on all four equations described in Table 6, using coefficients generated by six-year and three-year pooling, and by individual year samples. All the indexes behave in a similar way, regardless of the specification or the pooling period, with only small differences in their absolute values. Table 8 presents the indexes calculated using specifications 1 and 3, for three different sample aggregations.

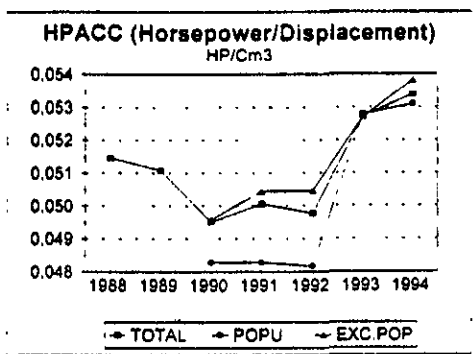


Figure 2a

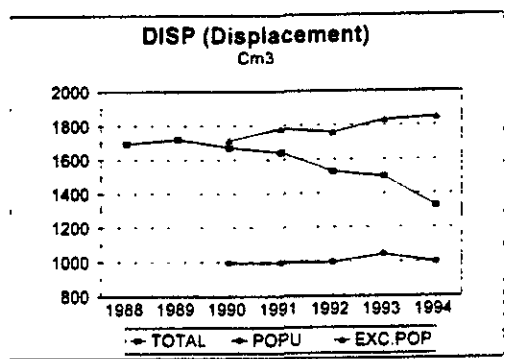


Figure 2b

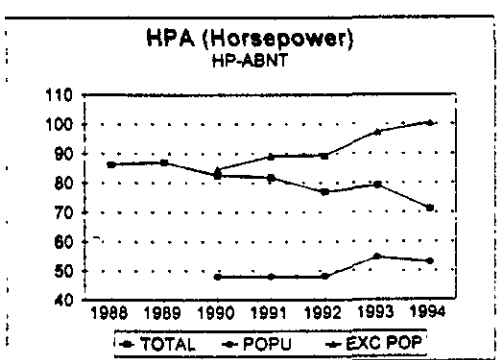


Figure 2c

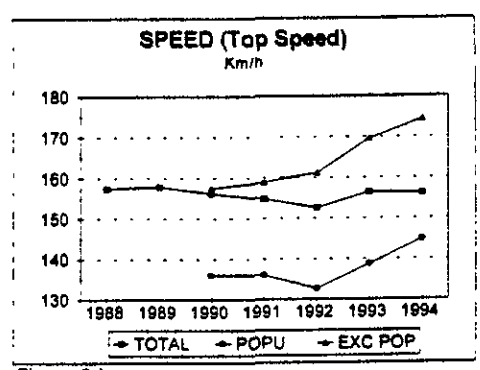


Figure 2d

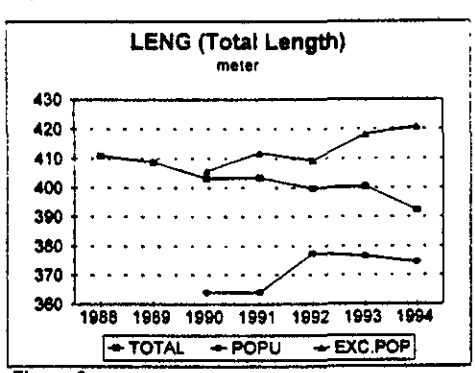


Figure 2e

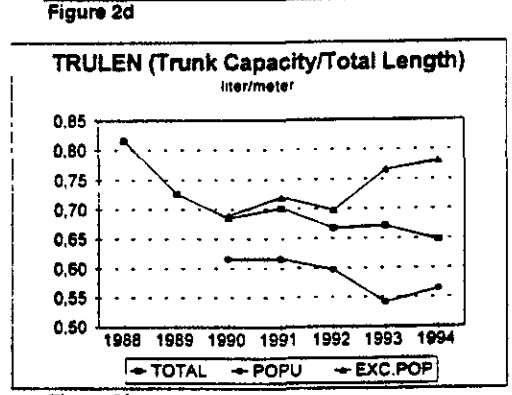


Figure 2f

To be continued

cont.

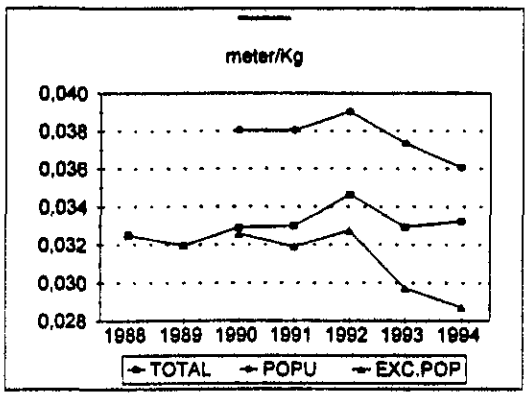


Figure 2g

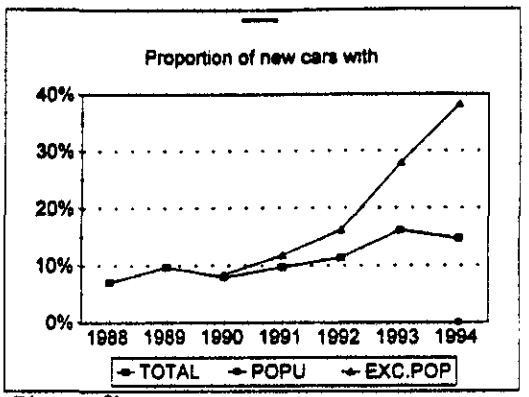


Figure 2h

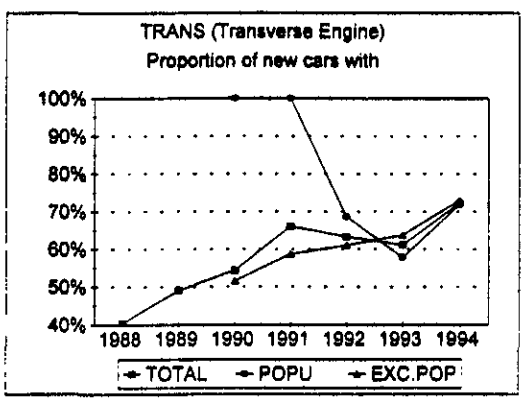


Figure 2i

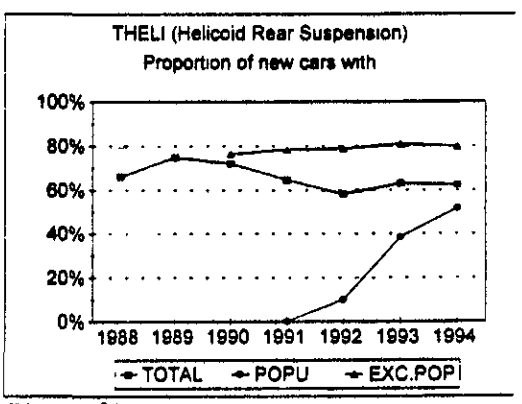


Figure 2j

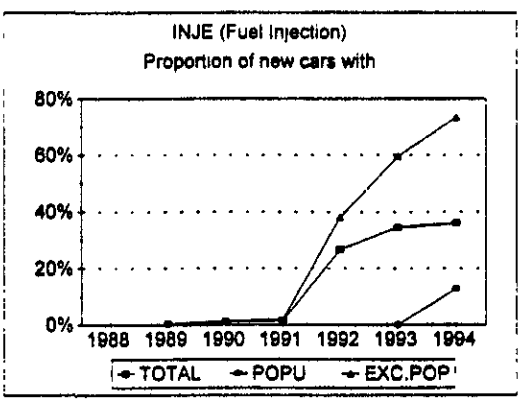


Figure 2k

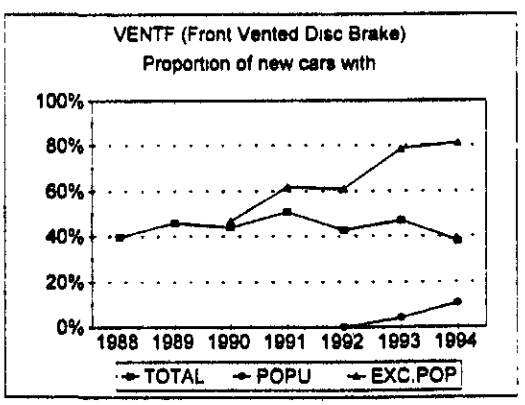


Figure 2l

Table 8
Quality Indexes* for Brazilian Passenger Cars excluding Station Wagon and "Popular Cars"

	Equation 1			Equation 3		
	Six-year Pooling	Three-year Pooling	Individual Years	Six-Year Pooling	Three-Year Pooling	Individual Years
1989	100	100	100	100	100	100
1990	97	96	96	99	99	99
1991	105	105	105	106	106	101
1992	104	104	104	105	105	105
1993	122	119	121	121	119	117
1994	132	127	128	130	126	122

* Average weighted by the version's share on total sample sales.

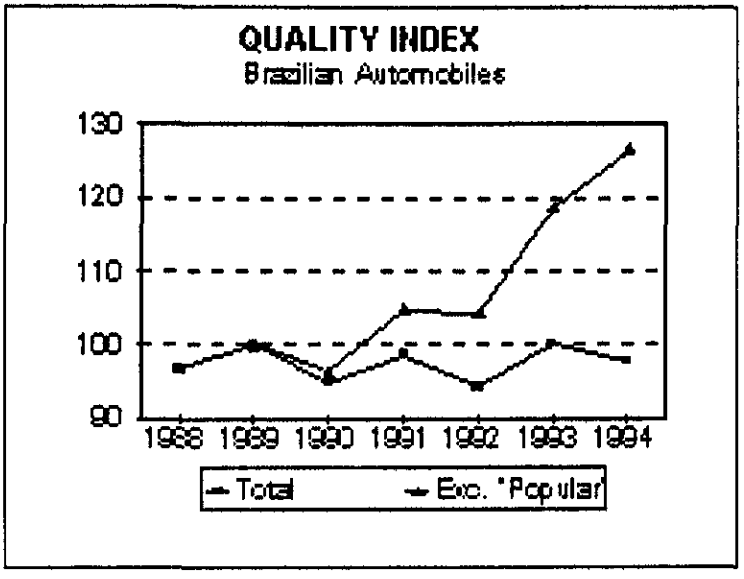
Figure 3 shows the evolution in the average quality of Brazilian automobiles, based on specification 1 with three-year pooling (the first two equations in Table 7).[16] It shows the behavior of the index for the whole sample of passenger cars (excluding station wagons). As mentioned earlier, it looks very similar to graphs of the index based on other specifications or sample aggregations.

If we were to ignore the introduction of "popular" models in 1992, we would conclude that the quality of Brazilian cars decreased after the trade liberalization. However, excluding this category from the sample inverts the result. From 1989 to 1994, "quality" of Brazilian passenger cars increased by 27 percent, with the biggest increases coming in 1993 and 1994, when quality increased by 22 percent (based on equation 1 with three-year pooling).

The "popular" segment was born in 1990, as the result of an agreement between government and industry. Pursuant to this agreement, the government reduced the tax on vehicles with an engine smaller than 1.000 cm^3, and manufacturers committed themselves to reduce their profit margins and keeping the cars' price stable (in US dollars). Thus, this market segment is basically composed of cars with engine volumes of less than one liter.

[16] Average weighted by the version's share on total sample sales.

Figure 3
Based on equation 1 with three-year pooling



Initially, automakers, with the exception of Fiat, were not prepared for or confident about this market. But, prompted by the large sales of the Fiat Uno Mille (the only "popular" car until 1992), the other firms decided to re-launch old models with smaller engines (a step backward, or quality "downgrading").[17] Quality did not appear to be a concern in the "popular" segment.

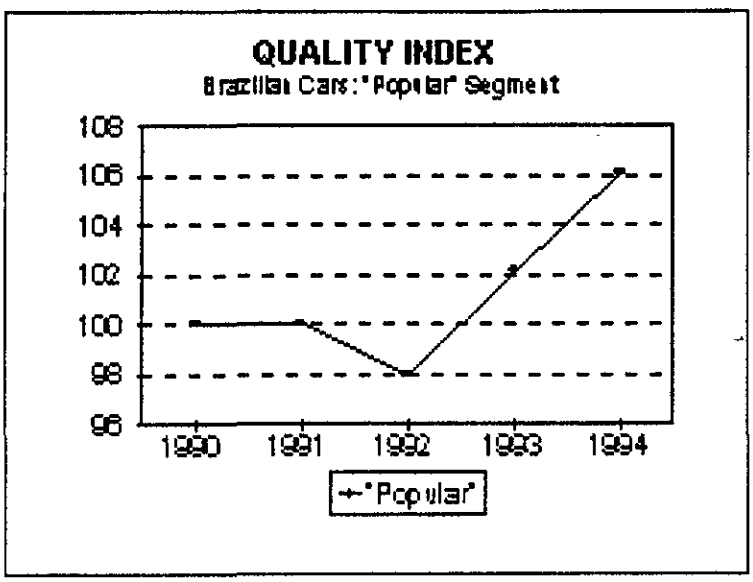
This situation changed in 1994. Attracted by a growing market, importers started to bring in cars with engines smaller than 1,000 cm^3. Still more important was the launching of a new model by General Motors of Brazil. The GM Corsa Wind ("popular") and the GM Corsa 1.4 (small segment) marked a turning point in the bottom segments of the Brazilian market. The Corsa, with its modern design and onboard technology, triggered a series of innovation in the "popular" and small car segments. For example, Fiat responded with a new version of its Uno Mille, the ELX, and Volkswagen speed up the "new Gol" project (the AB9), launching the new car in 1995.[18]

[17] General Motors entered the "popular" segment in 1992, with its 20-year old Chevette. Next came Autolatina, Volkswagen Division, with its 13-year old Gol. In 1993, the 11-year old Ford Escort entered the segment and the old Fusca (VW "Beetle") was brought back to life.

[18] General Motor, responding to the decline in its market share, expedited the launching of its new model. The Corsa was introduced in Brazil just one year after its debut in Europe. See **Quatro Rodas**, April 1994, p. 39-49; September 1994, p. 33-41; and January 1995, p. 32-41.

Thus, even in the lower segment of the Brazilian market, quality has improved. Figure 4, depicts the quality index for the "popular" segment, using the estimates from equation 1 with three-year pooling. As it shows, by the end of 1994, the average quality on this segment had increased by 6 percent since its inception in 1990.

Figure 4
Based on equation 1 with three-year pooling



6 - Conclusion

This study has shown that trade liberalization had a significant impact on the quality of the Brazilian automobiles. Moreover, it has demonstrated that the impact was positive. The evidence here presented supports my initial hypothesis that a gradual liberalization policy would provide both the time and incentive for domestic firms to catch up with world state-of-the-art technology.

The Brazilian market is highly concentrated. Until the breakdown of the joint-venture between Volkswagen and Ford in 1994, the entire market was shared by only three firms. Protection against imports was total and price was controlled by the government. Conditions were ideal for a "live and let live" philosophy.

The opening process provided the competitive stimulus needed to hasten quality improvement. Furthermore, imports of parts and components have allowed firms to incorporate new technologies without significantly increasing production costs, until domestic suppliers become better prepared to supply those inputs.[19] Moreover, gradualism allowed firms time to adjust their production methods and kept the expected payoff of the fight strategy positive. Thus, the Brazilian experience proves that trade liberalization can spur the adoption of new technology.

Unfortunately, the government deviated from the main policy goal, switching its focus from industrial modernization to price stabilization. By accelerating the opening process, the government not only risked killing the patient with an overdose, but undermined the credibility of its policy when it was forced to retreat.

[19] Sindipeças (1994, p. 33), shows that after entering the market with a large number (by Brazilian standards) of imported parts and components, the automakers ultimately re-directed their purchases to domestic suppliers.

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