MEASURING THE PERFORMANCE OF A PROTECTED INFANT INDUSTRY: THE CASE OF BRAZILIAN MICROCOMPUTERS

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Abstract—Until the beginnings of the Collor presidency in 1990, the Brazilian government strongly protected domestic producers of electronics goods. Using hedonic methods we analyze systematic evidence of the performance of the Brazilian microcomputer industry and compare it with international standards. Our analysis highlights rapid rates of advance in Brazil but lower rates than potential international competition. Technical frontiers typically lagged price/performance practices in international markets by at least three years and by as much as five. Foregone buyer surplus due to protection had to be quite high, approaching 20% of domestic expenditure on microcomputers.

I. Introduction

UNTIL the beginnings of the Collor presidency in 1990, the Brazilian government strongly protected domestic producers of electronics goods. The justification and policies for protecting "informatics" producers changed over the 1970s and 1980s, but the character of the outcome did not. Many anecdotes suggest that the policies failed to achieve their stated goals in many markets. Most observers argue that Brazilian firms did not come close to reaching parity with their potential international competitors in most markets (e.g., Reyes et al. (1990) and SEI (1988)). These laws and their consequences contain important lessons about how and why government nurturing of high-technology industries may fail (see Luzio (1993) for a review).

In this paper we move beyond the anecdotes. We provide and analyze systematic quantitative evidence of the performance of Brazilian microcomputer suppliers. We chose to study microcomputers because of their importance in the world data-processing market. In addition, the performance of this industry is better documented than any other. Because the Brazilian domestic market was largely dominated by Brazilian versions of IBM-PCs and Apple clones, we can directly compare the performance of the Brazilian industry with potential international competitors.

Our data set provides one novelty of this study—it is an eight year time series of price and performance characteristics for all Brazilian-produced microcomputers. Our methods are not novel in the economics of technical change: we employ standard hedonic techniques (Berndt and Griliches (1993)) to evaluate the rate of advance in the Brazilian industry. However, these methods are not common to studies of infant industries, perhaps because the necessary data are rarely available. So another novelty is our application of hedonics to evaluate the performance of the Brazilian industry relative to international standards. We think that the success of the methods here (and the increasing availability of product market data) may suggest similar applications in related issues of development economics.

Our quantitative analysis provides measures of the industry's development. First, we show that the Brazilian PC industry's price/performance often advanced at a rate that was comparable to international rates of advance. Second, despite this advance, the Brazilian industry never caught up to the leaders. The prices of domestically produced Brazilian PCs started higher and always stayed higher than their potential international competition. A similar computer model cost between 70% and 100% more in Brazil than in international markets. Technical frontiers typically lagged price/performance practices in international markets by at least 3 years and as much as 5. Third, we calculate a lower bound estimate for the opportunity cost of protecting the microcomputer industry rather than opening up to international markets. Foregone buyer surplus was on the order of 143.3 million U.S. dollars per year, or 33% of the average annual expenditure

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on domestically produced microcomputers, during 1984–88. At that same period of time, producer surplus was on average 58.5 million U.S. dollars per year, or roughly 13% of annual expenditure. Thus, the average opportunity cost for protecting microcomputer manufacturers was around 20% of average annual sales, during 1984–88. Fourth, our measurement framework confirms that the installation of the Collor regime dramatically affected the performance of Brazilian firms. Brazilian suppliers and buyers reacted quickly to Collor's public promise to dismantle the previous protective informatics policy. Domestic firms slashed prices, shut down inefficient product lines, and those remaining quickly came much closer to international price/performance standards.

To begin with, we briefly review the history of the informatics laws in Brazil. Then we discuss the data and present hedonic analysis of the industry's performance. We finish with a comparison of Brazilian performance against international standards. This comparison leads to an estimate of the opportunity costs to Brazil of protecting their domestic microcomputer industry.

II. A Brief History of the Informatics Laws

In 1977 the Brazilian military government initiated policies designed to protect domestic "informatics" firms, building on a history of protecting other domestic firms (Tigre (1983), Evans (1986)). In contrast with the previous experiences with import substitution (see Baer (1988, 1989), Fishlow (1990)), the informatics policy was characterized by the pursuit of technological autonomy and the almost absolute exclusion of foreign companies.[1] The scope of the protection initially extended to micro and minicomputers, but gradually expanded to a wide variety of data-processing devices and their inputs.

The laws differed in their effectiveness over time and between different types of microcomputer buyers. Large business and public sector buyers could not evade the trade-barrier, because they were too easy a target for enforcement raids. In contrast, smugglers dominated the market for small purchases. In the latter case, the buyer had to rely on an illegal service sector in the event of technical problems. Many anecdotes suggest that the majority of individual buyers went outside legal channels because the illegal imports were technically better. By some estimates, smuggling amounted to 65% of the total PC market by 1991 (*Chicago Tribune*, 11/04/91).

Since the domestic firms did not produce for export, they produced almost exclusively for large domestic firms and public sector buyers. Table 1 presents the history of the sales of legally-supplied computers. Ten major producers dominated the domestic microcomputer industry throughout the 1980s by supplying around 80% of total legally-supplied sales. Brazilian firms specialized

[1] For example, foreign companies, such as IBM and Burroughs, were allowed to produce mainframes, but they were completly excluded from the microcomputer sector.

TABLE 1.—TOTAL VALUE (MILLIONS OF REAL CR$)[a] AND QUANTITY PRODUCED OF SMALL-SIZE COMPUTERS COMPARED TO MICROCOMPUTERS (REFERRED TO AS "MICROS")

Year	Total Value of all Small Computers	Total Value of Micros	%	Total Units of Small Computers	Total Units of Micros	%
1980	18.61	13.59	73	1414	614	43
1981	31.52	22.69	72	2307	1516	66
1982	62.69	52.03	83	23432	22459	96
1983	54.07	46.5	86	56464	55711	99
1984	70.37	63.33	90	90101	89272	99
1985	146.43	108.36	74	158429	157338	99
1986	240.41	189.92	79	185875	183056	98
1987	118.14	98.06	83	141072	138874	98
1988	215.54	140.1	65	72208	70534	98
1989	259.21	189.22	73	95408	92461	97
1990	223.68	163.29	73	102452	99020	97

Source: The figures were computed based on data from SEI (1987, 1989), DEPIN (1991).
[a] The real Cr$ values were calculated based on the accumulated index of inflation (IGP with 1980 = 100), in order to avoid eventual distortions caused by currency depreciation from government's macroeconomic policies.

TABLE 2.—QUANTITY PRODUCED[a] AND VALUE (MILLIONS OF REAL CR$) OF MICROCOMPUTERS PRODUCED

Year	Value 8 Bit	%	Value 16 Bit	%	Units 8 Bit	%	Units 16 Bit	%
1985	68.65	63	34.97	32	147603	94	9735	6
1986	59.2	31	124.17	65	144900	79	38156	21
1987	18.05	18	71.78	73	92032	66	46842	34
1988	9.64	7	126.67	90	21350	30	48930	69
1989	10.36	5	158.58	84	14875	16	75366	82
1990	22.81	14	120.49	74	20830	21	71938	73

Source: Real values were computed based on SEI (1989) and Depin (1991). Note that the percentage values refer to the total of the microcomputer sector from table 2.1.

[a] The number of units produced changed dramatically from 1987 to 1988 due to the difference in the sample of firms. Thus, the table should be analyzed in relative rather than absolute terms.

in producing reverse-engineered clones of American-firm designs, first the 8-bit designs and then 16-bit designs. Systems using every known hardware architecture became available at one time or another, including those using CP/M operating system, IBM-PC clones using MS-DOS, and clones of Apple corporation's designs. Following the diffusion patterns in the United States, IBM-PC clones based on Intel chips became the dominant design in Brazil by the mid 1980s.[2] Table 2 presents market share of 8 and 16 bit designs.

By the end of the 1980s, the informatics laws were widely perceived as a costly nuisance at best and, at worst, a costly impediment to productivity advance in export-oriented industries, particularly those using numerically controlled machine tools (Kang and Steinmueller (1991)), such as automobile production. The laws had little popular support. During the election campaign of 1990, Collor promised to phase-out protection and dismantle the agencies enforcing the laws by the end of 1992. After his ascension to office, he announced a program to put these plans into effect, which produced dramatic (and immediate) results. Buyers curtailed their purchases of domestic products because they anticipated easier access to international markets and weak enforcement of the trade barriers. Several domestic firms quickly went into a dramatic decline. Many Brazilian engineers lost their jobs and those who remained eventually became sales representatives of the joint ventures formed with multinational companies.

Fifteen years of informatics policy had clearly failed to develop a domestic industry with technology autonomy and competitive prices. Brazilian firms had not caught up to their international counterparts. Many reasons have been offered for this, such as (1) Imported chips and domestically produced peripherals (e.g., hard disks), which constituted a large expense in the basic processor, were costly to obtain (Tigre (1989)). (2) Domestic content laws forced Brazilian computer manufacturers to use domestic suppliers for inputs. However, the industries that supplied basic microelectronic inputs, such as transistors, capacitors and picture tubes, were highly concentrated and not internationally competitive. Prices were around 2 to 5 times the international levels (Paiva (1988), p. 226). (3) Burdensome bureaucratic requirements and misguided sectorial policies limited competition and the entry of new suppliers (Spiller (1987a, b)). Luzio (1993) contains a more developed discussion of these factors.

III. Data

The data used in this paper come from two sources. Some of them, such as those shown already, come from reports compiled by the Special Secretariat for Informatics (SEI), the Brazilian agency primarily in charge of enforcing the informatics laws. A compilation of these data can be found in Luzio (1993). The novel data set in this paper, on the performance of individual computer models, comes from the price lists published by the newspaper *A Folha de São Paulo* over eight consecutive years. The data set extends over thirty-one quarters, from October 1984 to July 1992. In the total there are 2,461 observations on 513 different computer models manufactured by Brazilian firms.

Each observation was described by 47 different variables, 40 of which were dummies. Most of

[2] For more on the U.S. development of microcomputing platforms, see Bresnahan and Greenstein (1992).

these variables mimic variables used in previous hedonic studies of computers (Berndt and Griliches (1993), Triplett (1989)). The characteristics of microcomputers were described by (1) the amount of megabytes of the hard drive, *LHRD* (= log(*HRD* + 1)): (2) the number of kilobytes that the floppy disk could read, *LFLP* (= log(*FLP* + 1)); (3) the amount of random access memory available in kilobytes, *LRAM* (= log(*RAM*)); and, (4) the number of other hardware devices, such as back-up tape, *LACC* (= log(*ACC* + 1). (5) In addition, price variables were computed in two forms: real cruzados (*LPBR*) and real dollars (*LPUS*).[3]

The dummy variables used were of four types. The first set of dummy variables described technical aspects such as (6) whether or not the equipment included a monitor, *MON* (= 1 if yes, zero otherwise); (7) the architecture followed, i.e., *TAPP* (= 1 if Apple clone, zero otherwise), *TIBM* (= 1 if IBM-PC clone) and *TOTH* (= 1 if an architecture different than IBM and Apple);[4] and (8) the number of bytes of the microprocessor, *P8* (= 1 if 8 bits, zero otherwise), *P16* (= 1 if 16 bits) and *P32* (= 1 if 32 bits or more). The second set of dummy variables described any unmeasured quality dimension (e.g., "reputation" and maintenance network) associated with the leading Brazilian producers, that is, the "make effect." The producers were classified in two groups: the top ten producers, *BTOP*, and the others *BOTH*. Table 3 includes a list of these characteristics and sample statistics.

The third type of dummies capture time effects on prices. There were 31 time dummies, one for each quarter, defined as *Tij*, where *i* is the quarter and *j* is the year (for example, *T*384 refers to the third quarter of 1984). Finally, the fourth type of dummy variable describes the age of model. As noted before, there are 9 age dummies: *Ai*, with *i* being the number of semesters of age, that is, $i = 0, 1, \ldots, 8$. So a model with $A4 = 1$ indicates that it has 4 semesters or 2 years of age. When a model's price is first published, $A0 = 1$. Table 4 lists the statistics for those variables.

Exact multicollinearity among some variables imposed restrictions to our analysis. For example, note the following identities:

$$BTOP + BOTH = 1,$$
$$P8 + P16 + P32 = 1,$$
$$TAPP + TOTH = P8,$$
$$TAPP + TIBM + TOTH = 1$$
$$TIBM = P16 + P32,$$

TABLE 4.—STATISTICS OF THE AGE DUMMIES

Variable	Mean	Std. Dev.
*A*0	.170	.376
*A*1	.255	.436
*A*2	.168	.373
*A*3	.085	.279
*A*4	.057	.232
*A*5	.031	.173
*A*6	.014	.116
*A*7	.010	.098
*A*8	.117	.107

[3] The real cruzado series was calculated using the IGP-DI price index with December 1989 = 100. The exchange rate used to compute the dollar values was the official rate.

[4] Note that all domestically produced PCs were clones of well-known, typically American, designs. However, there was no Brazilian production of PCs by American firms such as IBM, Apple, and so on.

TABLE 3.—MEAN, STANDARD DEVIATION, MINIMUM AND MAXIMUM VALUES OF CHARACTERISTICS VARIABLES

Variable	Mean	Std. Dev.	Min. Value	Max. Value
PBR	530,060	491,480	4,724	4,964,000
PUS	3889.5	3189.3	30	27,460
RAM	666.8	710	2	4096
FLP	405.4	265.6	0	1000
HRD	9.3	16.2	0	160
ACC	0.04	0.2	0	1
MON	0.831	0.375	0	1
TAPP	0.118	0.323	0	1
TIBM	0.7725	0.419	0	1
TOTH	0.109	0.312	0	1
BTOP	0.2372	0.426	0	1
BOTH	0.763	0.426	0	1
*P*8	0.228	0.419	0	1
*P*16	0.729	0.445	0	1
*P*32	0.044	0.215	0	1

and

$TIBM + P8 = 1.$

As a consequence, the variables *BOTH*, *P*8, *TIBM* and *TOTH* were not used in the regressions below. These exclusions affect the interpretation of the coefficients of the remaining variables. For example, the coefficient of *TAPP* indicates the value of Apple technology relative to other technologies, excluding IBM clones, which is captured by *P*16 and *P*32. Moreover, due to the fact that the price of most of the models with technologies other than Apple and IBM did not include a monitor, the coefficient of *MON* reflects not only the value of a system with a monitor, but also the fact that the computer is either an IBM or an Apple clone.

TABLE 5.—RESULTS FROM REGRESSION (4) FOR ALL MANUFACTURERS

Variable	*PUS$*	*PBR*
Constant	4.639[a]	10.203[a]
	(0.126)	(0.137)
LRAM	0.361[a]	0.361[a]
	(0.020)	(0.020)
LFLP	0.091[a]	0.084[a]
	(0.007)	(0.007)
LHRD	0.136[a]	0.136[a]
	(0.007)	(0.007)
LACC	0.443[a]	0.031[a]
	(0.07)	(0.001)
MON	1.016[a]	1.053[a]
	(0.046)	(0.046)
TAPP	0.437[a]	0.451[a]
	(0.045)	(0.045)
BTOP	−0.033	−0.030
	(0.025)	(0.025)
*P*16	0.250[a]	0.266[a]
	(0.054)	(0.054)
*P*32	0.626[a]	0.647[a]
	(0.083)	(0.083)
R^2	0.811	0.805
No. Obs.	2567	2567

[a] The estimate is statistically different than zero at the 1% significance level.

IV. The Performance of the Brazilian Computer Industry

We divide our analysis into two sections. This section performs a standard hedonic analysis of computer model data. The next section compares the Brazilian performance against the U.S. industry, which stands in for international best practice.

We follow standard hedonic techniques for estimating technical change in a differentiated product industry. We estimate an equation of the form:

$$\ln p_{it} = \alpha_i + \gamma_{1i} + \varphi_{0i} + \Sigma\gamma_t D_{ti} + \Sigma\varphi_j A_{jit} + \Sigma B_k \ln X_{kit} + \mu_{it}$$

where p_{it} is the log of the price of computer model i in time t, X_{kit} are its k characteristics, D_{ti} and Ajt are time and age dummies, respectively, and μ_{it} is iid across observations. We use γ_t to compute an index of the change in prices not accounted for by product characteristics. That is, we estimate P_t/P_1 by $100 * \exp(\gamma_t - \gamma_1)$ for all t.[5]

As explained above, we use two different price variables. One is standardized in Brazilian cruzeiros and the other in U.S. dollars. While the two monetary units should provide the same results, at some point we need to denominate our index in real U.S. dollars in order to make it comparable with other indexes.[6] Tables 5, 6 and 7 present our estimates of the hedonic equation for each different type of price and for the sample with all firms. The estimates of B are not very sensitive to changes in monetary standard, but the estimates of the real price index do change in a few unsurprising ways. We describe these in turn.

As in previous estimates on U.S. data (Berndt and Griliches (1993)), characteristics of the computer system positively predict its prices. Among *LRAM*, *LFLP*, *LHRD* and *LACC*, the estimated

[5] As is well known (Berndt (1991)), these indexes are biased estimates of the rate of technical change. To correct for the bias we can employ the approximation used by previous hedonic researchers (Triplett (1989)), i.e., add half of the squared standard error to the estimate before taking the exponential. Because of the low standard errors in our estimates, there is little difference between the biased and corrected unbiased indexes.

[6] Any large difference between the two would suggest estimating our index in cruzeros, then translating it into dollars with a Purchasing Power Parity index (PPP). We do not do this for several reasons. First, the macroeconomic instability of Brazil over this time period makes use of a constant PPP in every year unrealistic. Second, there is no time series on PPP available for the period in study, but plenty of evidence of changes to the PPP (for more details, see Summers and Heston (1991)). Third, because we are more interested in comparing two products that could potentially compete on international markets (at that period's prevailing exchange rate), we felt there was merit in using official exchange rates, as all legal buyers had to do.

TABLE 6.—ESTIMATES OF AGE COEFFICIENTS

Variable	*PUS*	*PBR*
*A*1	−0.031	−0.030
	(0.025)	(0.025)
*A*2	−0.081[a]	−0.081[a]
	(0.029)	(0.029)
*A*3	−0.058	−0.056
	(0.037)	(0.037)
*A*4	0.012	−0.013
	(0.044)	(0.044)
*A*5	−0.029	−0.030
	(0.058)	(0.058)
*A*6	0.021	0.019
	(0.083)	(0.083)
*A*7	0.297[a]	0.295[a]
	(0.098)	(0.098)
*A*8	0.327[a]	0.330[a]
	(0.092)	(0.092)

[a] The estimate is statistically different than zero at the 1% significance level.

coefficients indicate that the RAM memory, hard disk capacity and accessories (for dollar price) contributed most to the price formation. These estimates are consistent with the producers' complaints about the high costs of microelectronic components and peripherals reported in Luzio (1993). However, since these estimates are in logs and not levels, one has to be cautious about inferring much about the cost of upgrades in practice. That is, even though the estimates of the *LRAM* coefficient is greater than *LFLP*'s, an upgrade of RAM memory could raise the price by less than an upgrade of floppy disks. For example, a floppy disk upgrade could involve a jump from 360 Kb to 720 Kb (100% change), while a memory upgrade could move from 640 Kb to 720 Kb. Thus, the final effects on prices of such upgrades would be 9.1% and 4.5%, respectively.

Interpreting the dummy variables of technical characteristics *MON*, *TAPP*, *BTOP*, *P*16, and *P*32, requires taking the exponent of the coefficient estimate. For example, the price ratio between a system with and without monitor would be 2.76 (= EXP(1.016)). Note that such a high ratio is due to the fact that *MON* captures not just the existence of a monitor, but it also distinguishes between machines based on Apple and IBM technologies from other architectures (Sinclair, MSX). In other words, a system based on IBM or Apple technology with a monitor would cost 2.76 times more than a system without monitor and based on different technologies. Such difference may arise because Apple and IBM clones were the most popular systems. In addition, note that a 16-bit machine would cost 1.28 (= EXP(0.25)) more than another with an 8-bit microprocessor. A 32-bit machine would cost 1.91 more than an 8-bit one.

The other set of dummy variables of interest is the one describing the models' ages. The means show that 59.3% of the observations were one-year old or younger. Only 12.7% of the observations were older than three years. Therefore, the majority of the microcomputer models (if proportional to the number of observations) either changed their technical characteristics often and/or they did not survive more than one year in the market, which suggests a high rate of exit. A similar phenomenon was also observed in Berndt and Griliches' data on the U.S. microcomputer industry. Rather than display the effect of this phenomenon on the estimated price indexes, as in Berndt and Griliches, we adopt a standard specification that uses only age and year effects. This is the easiest specification to use and our qualitative results are not sensitive to this standardization.

Most of the estimates of the age coefficients indicate that young models were cheaper than old ones. For example, the ratio of the price of a model of one-year old or less to other models is 0.92 (= EXP(−0.81)), while the ratio of a model of four-years old is 1.39 (= EXP(0.327)). This result suggests that consumers valued models that survived longer years more than new ones. Moreover, new models were sold at a discount relative to older models, which may be a consequence of lower production costs. Alternatively, the discount on new equipment could be a form of remuneration to the consumer willing to take the risk of buying a model whose production could be discontinued after a year. If so, old models had a price premium for the recognition of a long track of marketing success, and therefore a stable maintenance network and resale price.

Table 7 and figure 1 present the implied price index for each set of estimates, averaging four quarters of change into one year's index. While the price indices fluctuate from one quarter to another, a steady downward decline is evident: −7.958% per quarter over all eight years of the sample. Two factors, both representing changes in Brazilian government policy, make an obvious

TABLE 7.—SUMMARY OF REGRESSION RESULTS FOR TIME DUMMIES (REAL DOLLARS AND REAL CRUZEIROS)

Variable	Estimate	Index	% Change	Estimate	Index	% Change
T484	0 (0)	1	—	0	1	—
T185	0.095 (0.131)	1.015	1.517	0.099 (0.131)	1.105	10.45
T285	0.063 (0.132)	0.905	−10.86	0.040 (0.132)	1.041	−5.77
T385	0.001 (0.134)	0.794	−12.27	−0.077 (0.133)	0.926	−11.04
T485	−0.018 (0.122)	0.771	−2.83	0.074 (0.122)	1.077	16.31
T186	−0.138 (0.124)	0.673	−12.74	−0.171 (0.124)	0.843	−21.75
T286	0.080 (0.120)	0.776	15.31	−0.012 (0.119)	0.989	17.34
T386	0.019 (0.118)	0.666	−14.24	−0.088 (0.118)	0.414	−58.17
T486	−0.031 (0.118)	0.609	−8.52	−0.158 (0.117)	0.854	106.49
T187	−0.160 (0.118)	0.502	−15.58	−0.334 [a] (0.116)	1.396	63.49
T287	−0.21 [b] (0.117)	0.450	−10.38	−0.408 [a] (0.116)	0.665	−52.36
T387	−0.409 [a] (0.117)	0.350	−22.18	−0.578 [a] (0.114)	0.561	−15.66
T487	−0524 [a] (0.115)	0.302	−13.73	−0.727 [a] (0.114)	0.484	−13.79
T188	−0.644 [a] (0.117)	0.261	−13.59	−0.904 [a] (0.116)	0.405	−16.24
T288	−0.543 [a] (0.121)	0.266	2.10	−0.820 [a] (0.121)	0.417	3.012
T388	−0.600 [a] (0.119)	0.235	−11.71	−0.874 [a] (0.118)	0.417	0
T488	−0.513 [a] (0.121)	1.048	345.63	−0.814 [a] (0.120)	0.443	6.19
T189	−0.540 [a] (0.125)	0.811	−22.65	−0.884 [a] (0.124)	0.413	−6.79
T289	−0.466 [a] (0.122)	0.741	−8.64	−0.983 [a] (0.122)	0.374	−9.39
T389	−0.894 [a] (0.127)	0.433	−41.52	−1.346 [a] (0.126)	0.260	−30.46
T489	−0.672 [a] (0.123)	0.486	12.27	−1.221 [a] (0.123)	0.295	13.29
T190	−0.872 [a] (0.124)	0.356	−26.82	−1.512 [a] (0.123)	0.221	−25.2
T290	−0.332 [a] (0.122)	0.548	53.90	−1.148 [a] (0.122)	0.317	43.84
T390	−0.595 [a] (0.122)	0.383	−30.11	−1.412 [a] (0.121)	0.244	−23.16
T490	−0.800 [a] (0.123)	0.288	−24.89	−1.544 [a] (0.122)	0.214	−12.35
T191	−1.339 [a] (0.123)	0.152	−47.02	−1.858 [a] (0.122)	0.156	−27.01
T291	−1.169 [a] (0.126)	0.170	11.76	−1.864 [a] (0.125)	0.155	−0.51
T391	−1.367 [a] (0.126)	0.134	−21.28	−2.055 [a] (0.125)	0.128	−17.46
T491	−1.817 [a] (0.126)	0.082	−38.60	−2.408 [a] (0.126)	0.090	−29.69
T192	−1.782 [a] (0.128)	0.082	−0.650	−2.428 [a] (0.129)	0.088	−2.04
T292	−1.892 [a] (0.129)	0.07	−13.90	−2.494 [a] (0.129)	0.083	−6.34
%AQGR 1984–1992			−7.958	%AQGR 1984–1992		−7.497
%AQGR•1984–1989			−4.587	%AQGR 1984–1989		−6.641
%AQGR 1990–1992			−14.96	%AQGR 1990–1992		−9.352

Note: Index computed as P_t/P_1 by $100 * \exp(\gamma_t - \gamma_1)$.
[a] The estimate is statistically different than zero at the 1% significance level.
[b] The estimate is statistically different than zero at the 5% significance level.

difference:

(1) The freeze of the official Cruzado/Dollar exchange rate from 3/1986 to 9/1986 and from 1/1989 to 3/1989 influenced the price index estimates during those months, which is clearly artificial. Once the freeze was lifted, the ratio of prices resorts back to its old pattern. Moreover, further fluctuations in the price index were provoked by the exchange rate policy of the first years of the 1990s. At that time, the government depreciated the exchange rate faster than the inflation rate and vice-versa (e.g., from 1990 to July of 1992, the cruzeiro depreciated 5,479%, while the inflation rate reached 4,593%).

(2) The election of President Collor (and the implied threat to eliminate informatics laws) is also evident. From 1984 to 1990 the rate of implied price decline is −4.587% per quarter. After 1990 the rate of implied price decline is −14.96% per quarter, with an enormous decline coming in 1990, right after the election.

These initial results support three conclusions. First, the Brazilian microcomputer industry, like its counterparts all over the world, continued to advance over the entire 8 years. Despite some variation in the measured rate of advance, the rate of advance was rapid overall. Second, the rate of advance significantly accelerated after the beginning of the Collor presidency. This

FIGURE 1.—HEDONIC PRICE INDEX IN BRAZIL IN 1984–92

change is consistent with anecdotes about dramatic exits of domestic firms in the 1990s. Third, denominating the indexes in either currency provides different perspectives on short-run technical change, but does not alter the inference about long-run technical change in this market.

V. The Opportunity Costs of Protection

We use two different standards for measuring the opportunity costs of protection. First, we directly compare levels and rates of change of price/performance in Brazil against similar price/performance measures in the United States, which proxies for best practice world-wide. Second, we estimate the changes in consumer and producer surpluses that would have occurred in Brazil had they had access to U.S. markets.

A. Comparison of Brazilian and International Technical Advance

We first estimate the relative size of prices in Brazil to U.S. prices in a given year, holding constant for system characteristics. We take the average system characteristics of a Brazilian system in 1984 and estimate its relative price in the United States and Brazil in 1984 by

$$\frac{P_{US}}{P_{Br}} = e^{[\alpha_{US} - \alpha_{Br} + \ln K_{Br_{84}}(B_{US} - B_{Br}) + D_{Br}(\gamma_{US} - \gamma_{Br})]}$$

where a system's price in the United States in 1984 is estimated using the coefficients in the similar specification of Berndt and Griliches (1993). We can extrapolate the relative prices between U.S. and Brazilian systems for all years after 1984 by using the estimated rates of change from our hedonic estimates and from their hedonic estimates. In other words, the U.S. prices start out much cheaper than the comparable Brazilian price; the change in the relative standing of the two countries' prices is a function of rates of change from the estimated hedonic indexes for each of the two countries.[7] This ap-

[7] We checked this procedure against the obvious alternative: not using the hedonic estimates and computing a relative comparison for each subsequent year. This requires that we use the mean system characteristics for 1985, 1986, and so on, and then computing the implied prices for the United States and Brazil in each year. We found no substantial differences in the estimates, so we only show one set.

TABLE 8.—SURPLUS CALCULATIONS (IN MILLIONS OF U.S. DOLLARS)

T	Sales	US/B Price Ratio	k	PS Gain	Lost CS	Lost CS as %GNP
1984	126.54	0.534	0.466	29.48	79.58	0.03
1985	383.87	0.633	0.367	70.44	179.38	0.07
1986	745.57	0.697	0.303	112.95	276.94	0.10
1987	644.00	0.844	0.156	50.23	112.15	0.04
1988	279.17	0.789	0.211	29.45	68.34	0.02

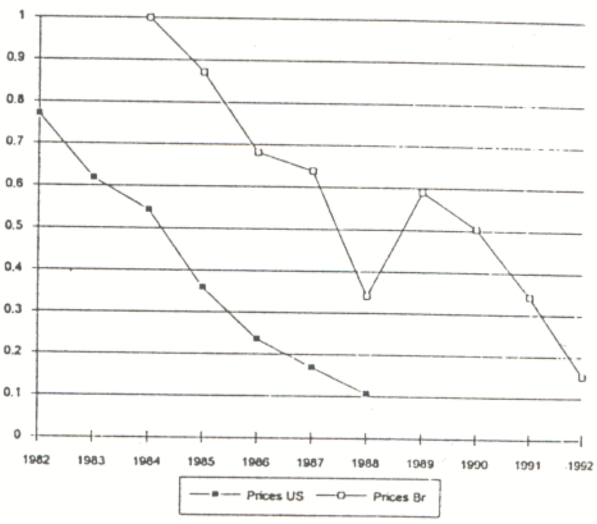
Source: Sales quantities reported in SEI (1987, p. 76), SEI (8/1989, p. 28) and DEPIN (1991, p. 56).

proach has the advantage that we can derive estimates comparing the United States and Brazil for each year even though we do not know the average characteristics of the systems available in the United States in each year of interest.[8]

Table 8 shows the price ratios for 1984 and for all subsequent years. In the first year, the U.S. computers were roughly half the price of their equivalent Brazilian counterparts (0.534). By 1988 the ratio was 0.789. Though the prices of Brazilian microcomputers did decline at a rapid rate, they never caught up with their U.S. counterparts in terms of price performance. While these short-term comparisons are mildly sensitive to exchange rate fluctuations, the long-term trends are clear.

We illustrate this comparison in figure 2. It compares the estimated price/performance marks for both the United States and Brazil over the years we have estimates. Notice that it is also possible to see how many years Brazilian microcomputers' prices/performance were behind U.S. prices/performance for equivalent systems. Brazil's 1985 price/performance represented the mid-1981 price/performance in the United States. By 1990, Brazil's price/performance was more than five years behind best practice in the United States. The gap widened from 1984 to 1990, with the exception of 1988–1989, in which the exchange rate is manipulated, as noted above. It fell considerably after 1990, as expected, reducing the technology gap to 4 years.

FIGURE 2.—TECHNOLOGICAL GAP



B. Consumer and Producer Surplus Estimates

We consider an alternative method for quantifying the opportunity costs of protection. We provide an estimate of the change in consumer surplus that would result from opening up the Brazilian market to cheaper outside imports. We do not wish to suggest that our estimate is exactly right. Rather, we wish to show that with a fairly simple and plausible model, the magnitude of lost consumer surplus must be large. We are convinced that any other estimate will show results of the same magnitude or more.

We adopt methodology first developed by Griliches (1958) and extended by Flamm (1987). Under a constant elasticity demand curve, $P = aQ^{-\epsilon}$, a second-order Taylor expansion for the gain in consumer surplus from a decrease in prices from P_0 to P_1 is

$$CS = kP_0\dot{Q}_0\left[1 - \left(k\frac{\epsilon}{2}\right)\right]$$

where ϵ is the absolute value of the price elasticity of demand; and k is the yield, or the gain

[8] There was no natural way to choose between the two indexes for making this projection. We took the average rate of change in the two Brazilian hedonic indexes. Thus, the Brazilian index in figures 1 and 2 differs slightly.

from the (marginal or average) cost reduction caused by the new technology. Thus, the yield k in the year i would be

$$k_i = 1 - \frac{P_{USi}}{P_{Bri}}.$$

Even though the price ratio cannot be observed precisely, we can reasonably use the 0.53 benchmark ratio. The yield for the subsequent years can be approximated using the rate of price change between the hedonic indexes in the United States and Brazil from 1984 to 1988, when the Berndt and Griliches (1993) study ends. For example, the yield of moving from the market reserve to free imports in 1985 would be

$$k_{85} = 1 - \frac{P_{US85}}{P_{BR85}}$$

where

$$\frac{P_{US85}}{P_{BR85}} = 0.53\frac{\left(1 - \dfrac{\Delta P_{HedoUS85-84}}{P_{HedoUS84}}\right)}{\left(1 - \dfrac{\Delta P_{HedoBr85-84}}{P_{HedoBr84}}\right)}.$$

Before reporting the results it is important to call attention to the fact that this estimate of the opportunity costs of the informatics laws is likely an underestimate of the true gains from bringing down barriers to foreign competition. First, consumer surplus is a partial equilibrium measure of opportunity costs, which ignores the general equilibrium benefits to downstream users of improved micro-computers (e.g., long-run changes in investment behavior). Second, constant price elasticity of demand is a strong assumption for a growing market undergoing rapid technical change. It provides no estimate of the benefit from increases in the variety of models available or an extension in the capabilities of models. Third, we use Flamm's estimates of the elasticity of demand for all computing equipment, estimated on U.S. data. His estimates are on the order of -1.5. More elastic demand for PCs alone, as is likely due to competition from smuggled PCs and other types of computers, would result in a much higher benefit from price decline than we estimate. Nonetheless, this measure provides a lower-bound ball-park estimate of the opportunity costs from a change in prices. Moreover, this methodology has not been used by any previous study of import protection that we are aware of.[9]

Table 8 presents the results. The consumer surplus ranged from 79.6 to 277.0 million dollars, during 1984–88, which are large amounts compared to the total expenditure on legal sales each year for the same period, which range from 126 to 745 million dollars. Over the whole period, the lost consumer surplus comes to 716.4 million or 33% of total expenditure on legal systems.

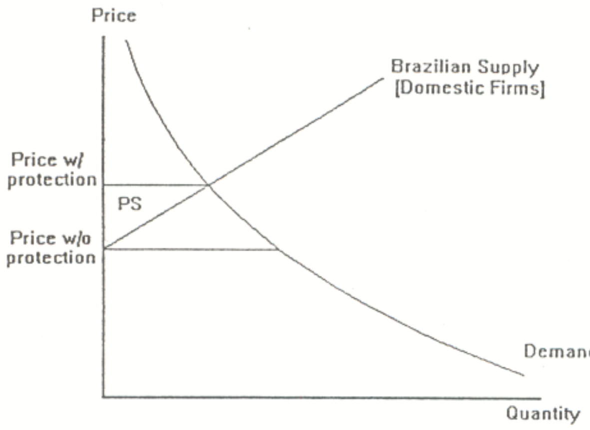
It is also possible to calculate an approximation of producer surplus. This is more difficult due to the lack of information about the elasticity of domestic supply or the levels of domestic costs of supply and how it changed over time. However, a simple model gives us a ball-park estimate.[10] The producer surplus can be approximated by assuming: (a) a linear upward sloping supply curve; (b) the origin of the supply curve of Brazilian producers before the market liberalization is equal to the equilibrium price after liberalization. The latter assumption is based on the fact that most, but not all, Brazilian firms shut down after liberalization, which implies that almost every firm was unwilling to supply any microcomputers at the new market conditions. See figure 3.

The resulting producer surplus for 1984, for example, is the area of a triangle with height equal to the equilibrium price in Brazil in 1984 minus the equilibrium price in the United States in the same year. The base of the triangle is the quantity of microcomputers sold in 1984. The average price in 1988 or any other year is calculated by the same method as described above. Table 8 lists the estimates of the producer surplus for 1984–88, which was on average 58.5 million dollars per year, resulting in a total gain for producers of 292.5 million dollars. This indicates that approximately 41% of consumer surplus (13.4% of total legal expenditure) was captured as producer surplus.

[9] Since all imports of foreign PCs were ostensibly blockaded, there was no official collection of tariff revenue in connection with the informatic laws. If there had been, it should be a part of welfare analysis. More generally, however, we are ignoring the costs of rent-seeking and corrupting behavior associated with enforcing and circumventing these laws.

[10] We are grateful to the anonymous referee for suggesting this procedure to us.

FIGURE 3.—MODEL FOR ESTIMATING PRODUCER SURPLUS



In sum, these figures demonstrate the large costs associated with protecting this industry. Not only did the Brazilian firms remain less efficient than international standards, but their product improved at a slower rate. The opportunity costs to users of protecting this industry had to be large.

VI. Conclusion

Personal computers were but one of many industries covered by the informatics laws in Brazil. It is an important and interesting case, because it is representative of all industries that grew up under the import protection. It also offers us an opportunity to understand the costs of protecting an industry, since there were well-documented international standards.

We found that the Brazilian PC industry advanced at a rate that was comparable to international rates of technical advance (or slightly slower), but the prices of legal Brazilian PCs started higher and stayed higher than their potential international competition. Technical frontiers perpetually lagged price/performance practices in international markets by three years and as much as five. The opportunity cost of following this protective policy rather than opening up to international markets (i.e., foregone surplus) was on the order of 716.4 million U.S. dollars, or roughly a third of the total expenditure on domestically produced microcomputers.

Further work should consider the efficacy of import protection of high-technology in light of these costs. Government policy for encouraging high-technology firms may have less costly approaches available, such as direct subsidies to research and development. In addition, further research should identify which aspects of the protection influenced the costs borne by Brazilian consumers of PCs. Luzio (1993) contains such a study.

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