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Brazilian Aerospace Manufacturing in Comparative Perspective: A Brazil/USA Comparison of Output and Productivity

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Abstract

A comparison of the performance of the Brazilian aerospace industry with that of the world leader in aerospace production, the USA, requires appropriate conversion rates. Following the methodology of the International Comparisons of Output and Productivity project (ICOP), we calculate unit value ratios for the aerospace industry based on ex-factory prices. So far no comparisons have been made for this sector, due to problems of disclosure in national statistics. In this paper, we have made adjustments to official data from industrial surveys using supplementary data on quantities and prices from a variety of other sources. Our 2005 unit value ratios for the aerospace industry are somewhat lower than updated UVRs from a previous ICOP study by Mulder et al *(2002) for the whole transport equipment branch, but the two estimates are in the same range. Our results on comparative labour productivity in aerospace point to more rapid catch up than in the transport sector as a whole. There was a period between 1999 and 2003, when the Brazilian aerospace industry clearly outperformed the United States. However, Brazil was unable to sustain this dramatic sectoral catch up. After 2003, firms disregarded the clear signals of shrinking value added and continued to increase the number of employees. As a result Brazil once again fell behind.*

Keywords: aerospace manufacturing, labour productivity growth, international comparison

JEL Codes: L62, O14, O15, O47

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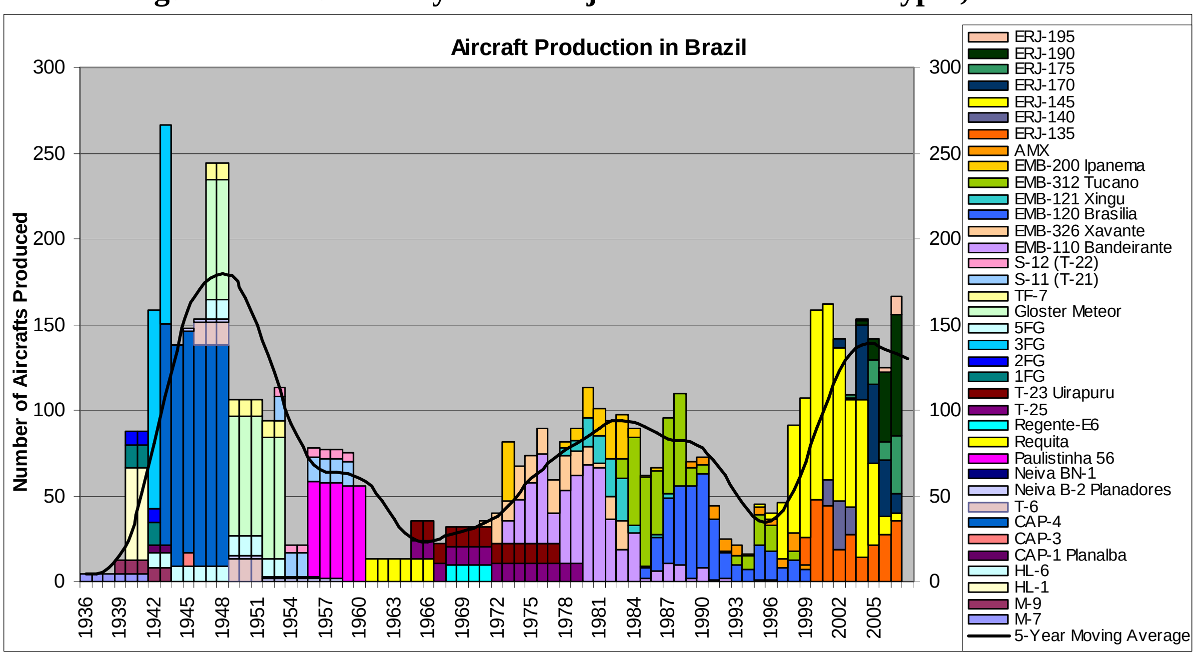
UNU-MERIT Working Papers intend to disseminate preliminary results of research carried out at the Centre to stimulate discussion on the issues raised.

1. The Brazilian aerospace industry

The aim of this paper is to chart the evolution of the Brazilian aerospace industry in an international comparative perspective. After a brief description of Brazilian production trends in section 1, the paper focuses on a systematic comparison of output and productivity trends in a binary comparison with the world's largest aerospace producer, the USA.

For over seven decades, Brazil has been accumulating experience in aircraft manufacturing. After mass-production of small planes for sporting, military and agricultural purposes, the industry shifted direction and engaged in the design and series production of commuter planes which became successful both in domestic and export markets. Figure 1 shows the production data for all the major Brazilian aircraft types since 1936. Three distinct product cycles can be distinguished: 1939-60, 1969-93 and 1996-2007. These cycles indicate the technological advance from the mainly single-seat, piston-engine planes of the 1930s-50s, to the turboprop commuter planes of the 1970s and 80s, and subsequently, to the state-of-the-art regional jets that highlight the Brazilian aerospace industry's capabilities from the mid-1990s onwards.

Figure 1 Production Cycles of Major Brazilian Aircraft types, 1936-2007

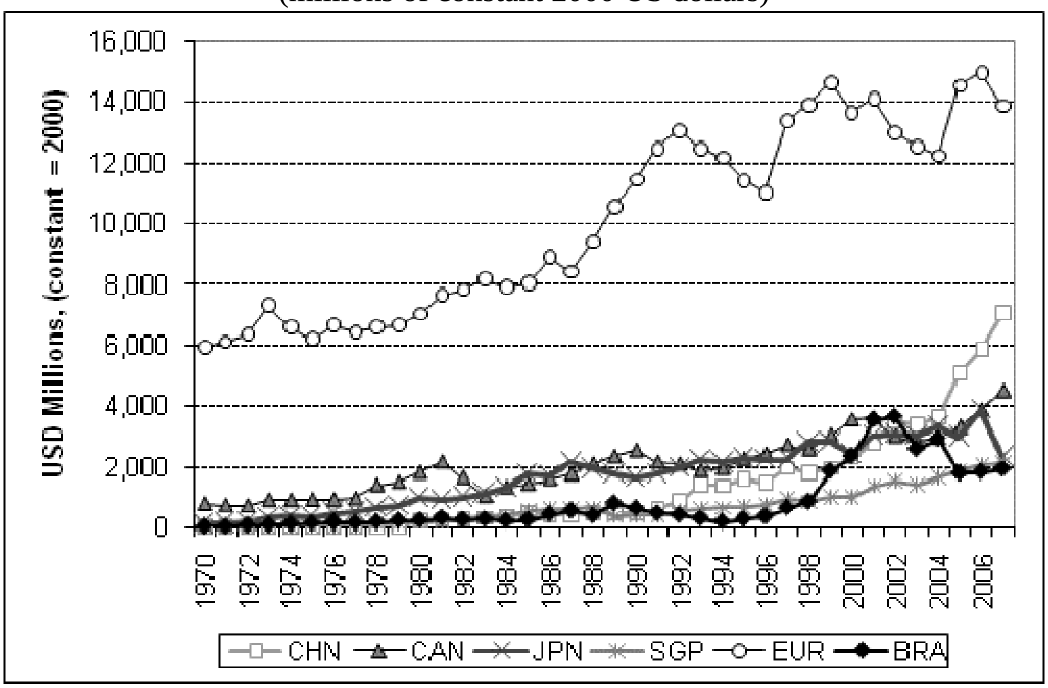


Source: own compilation based on Cabral (1987); Cassiolato *et al* (2002), Embraer Annual Reports, The *Airlinerlist* database <http://www.airlinerlist.com> (downloaded 2009 Feb); *Flight International*, various issues.
Note: When exact annual production data are lacking before 1969, we divided the total number produced by the years of production.; Embraer Legacy executive jets are included in the ERJ-135 series; figures after 1970 exclude general aviation aircraft, including license-produced Pipers and the upgraded versions of the Ipanema (EMB-201 and 202).

The three periods also reflect three major forms of industrial organization. Before and during World War II, the industry was dominated by a few private producers competing for private customers as well as responding to government procurement incentives. After a long post-war reorganization period, a state-owned company Embraer emerged as the major player in the industry. Following a crisis in the industry at the beginning of the 1990s,[1] Embraer was privatized, with its shares being held by Brazilian investors. It established a structure of global supply chain through risk sharing partnerships.[2]

The Brazilian aerospace industry[3] is often mentioned as an example of successful catch up of a high-tech sector in an emerging economy. In an international comparison of aerospace value added, we find that by the first years of the 21st century, Brazil has emerged as a major player in aerospace, approaching the value added shares of established advanced country producers such as Japan, Canada or France (see Figure 2). The global aerospace industry is dominated by the United States, which remains far ahead of all other competitors. At its peak production in 2001, Brazil merely reached 5% of US value added. The combined value added of all European countries was only 26 per cent of US value added.

Figure 2 Value Added in the Aerospace Sector, Selected Countries, 1970-2007
(millions of constant 2000 US dollars)



Sources: Chinese National Bureau of Statistics, various yearbooks; EU-KLEMS, IBGE, OECD STAN, UNIDO. Constant 2000 prices in national currencies were calculated using value added deflators for the transport equipment industry. The following unit value ratios were applied for conversion (from GGDC, Szirmai *et al*, 2005 and own calculations as described in paper; updated to 2000): Brazil: 1.09; Canada: 1.8; China: 4.6; Japan: 125.2; Europe includes the Euro-zone average of 1.85, Sweden: 19,6, United Kingdom: 1.44.)
Note: CHN=China, CAN=Canada, JPN=Japan, SGP=Singapore, EUR=European Union, BRA=Brazil.

[1] Frischtak (1992) provides a comprehensive analysis of the economic, financial and technological background of the crisis of Embraer.
[2] For a detailed discussion see Cassiolato *et al* (2002) or Marques (2004).
[3] Following the ISIC Rev.3. 353, the aerospace industry includes the production aircraft, spacecraft, engines and propulsions and components thereof. The spacecraft segment is not significant in Brazil. The focus is aircraft.

2. An industry of origin approach to output and productivity comparisons

The basic problem with aggregating output or comparing the levels of labour productivity of an industry across countries is the conversion of values to a common currency. The various shortcomings of official exchange rates and aggregate, expenditure-based purchasing power parities (PPPs) are well established (Maddison and van Ark 1988; van Ark 1993). According to Timmer (2000), the main arguments against using official exchange rates for comparing industries can be summarized as follows. First, they indicate the relative price levels of internationally tradable goods and services in an economy and disregard non-tradables. Next exchange rates are often distorted by governments for domestic political and economic reasons. Exchange rates are also influenced by speculation and rapid international capital movements. Finally, exchange rates provide a single converter for all goods and services produced in the economy. They do not allow for sector specific converters.

Purchasing power parities, such as the ones published by the World Bank, OECD or Eurostat address a number of these shortcomings. PPPs are calculated in the tradition of Kravis, Heston and Summers (1982) and are based on consumer prices and expenditure categories in national accounts. There are, however, several problems with the use of PPPs for sectoral productivity comparisons. They include trade and transport margins and indirect taxes and subsidies; they include import prices but exclude export prices, but most importantly, PPPs are based on final expenditures. They are useful for converting expenditure categories, but do not provide industry-specific conversion factors from the production side.

Therefore, when possible, sectoral unit value ratios (UVRs) derived from the International Comparison of Output and Productivity (ICOP) methodology are used to convert output values and value added in national currencies for purposes of sectoral international comparisons. In short, according to this tradition developed by Maddison and van Ark (1988), van Ark (1993) and advanced by Timmer (1996) a sample of products from the countries in a comparison are matched and unit value ratios (UVRs) are calculated using ex-factory unit values. These UVRs provide conversion ratios at the industry and branch level, and can be aggregated to the national level. Since the technical details of the ICOP methodology have been presented in dozens of studies,[4] we refrain from further detail here; interested readers can find a summary in Annex I.

A major advantage of this method is that it offers industry-specific unit value ratios based on production data, which is ideal for sectoral comparisons between countries.

[4] The richest collection of such studies has been published in the *Research Memoranda* series of the Groningen Growth and Development Centre (GGDC).

Since the 1980s, UVRs have been meticulously calculated and published at the two-digit branch level for a wide range of countries.[5] (The aerospace industry forms part of transportation equipment manufacturing both in the ISIC Rev.2 and Rev.3 classification.)

The feasibility of industry-of-origin comparisons may be constrained by the availability of product-level output data in official statistical sources. Industries characterized by monopolies are very likely to remain beyond the scope of comparison because their production data are not disclosed in national statistics in order to avoid identification of a single firm. Thus, it is not surprising that the aerospace industry, especially in emerging economies, is missing from all cross-country comparisons. Comparisons for the more aggregate 'transportation equipment industry' are based on samples of products from automobile manufacturing, railway manufacturing or ship building industries. The assumption is made that the unit values ratios derived from matches in these industries are also applicable to Aerospace output. The technologically complex nature of the products and the existence of comparable safety standards arguably make these 'sister sectors' acceptable proxies. However, the assumption that unit value ratios in aerospace are similar to those for other transport subsectors remains to be tested empirically.

The limited number of firms in a sector can result in non-disclosure of data in national statistics, but this can also be a virtue. Production statistics can be traced from published company figures to form the basis of alternative calculations. If company reports reveal the value and volume of the annual production of certain major products, a sample is at hand to execute the ICOP-style calculations.

Unfortunately, in the case of an industry that is considered strategic for national security, such as aerospace, further obstacles emerge. Production detail of defence equipment is rarely revealed, and state-owned companies are often less obliged to publish reports as detailed as those published by joint-stock companies. Company-report-based data will most likely be only available for countries where the bulk of production caters to the civilian market, rather than to military demand.

In 1994, the largest state-owned aircraft producing company of Brazil (Embraer)[6] was privatized and its shares have since been traded on Wall Street. The history of aircraft manufacturing in Brazil and of Embraer is discussed at length in Vertesy (forthcoming). Let it suffice here to state that this act made the company successful once again, as many observers have noted (Goldstein 2002a, 2002b, Cassiolato *et al* 2002, Goldstein and McGuire 2004, Marques, 2004, Montoro *et al*, 2009) and, most importantly, as is shown by evidence from annual reports. Based on available company data, we make an attempt in this

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[5] For a complete list of countries, please refer to the GGDC ICOP Database 1997 Benchmark, http://www.ggdc.net. The following selected papers summarize the latest calculation for emerging countries in our scope: Brazil and Mexico (Mulder *et al* 2002), China (Szirmai *et al* 2005), Indonesia, South Korea and Taiwan (Stuivenwold and Timmer 2003) and South Africa (van Dijk 2002).

[6] Although the number of enterprises in the sector has been well over a hundred, Embraer clearly dominates the industry (see Annex III.2 table).

paper to estimate industry-specific unit value ratios to convert the value added of Brazilian aerospace industry into US dollars for the benchmark year 2005. These unit values ratios will be compared with updated unit value ratios for the transportation equipment sector, estimated by Mulder *et al* (2002), as well as with the official exchange rate.

In this paper, we estimate unit value ratios in order to compare the output and productivity of the Brazilian and United States' aerospace industries. There are three main reasons for using the US as a benchmark. First, the USA accounts for the largest share of the global aerospace production. Second, reliable, detailed product-level manufacturing statistics are available over a longer time span. Finally, the USA has been the benchmark country for the majority of comparisons in the ICOP literature.

2005 was selected as the benchmark year. The choice of an appropriate benchmark year is of crucial importance for a volatile industry such as aerospace, especially if the business cycles of the two countries being compared do not coincide. The choice for 2005 was motivated by four arguments. First, production in Brazil in 2005 was substantial in volume and offered a broad variety of products, indicative of the capabilities of the industry. Second, it is a relatively recent year, which comes after the currency crises which affected Brazil so heavily and after the industrial reorganization following the privatization of Embraer. (The previous study by Mulder *et al* (2002) took 1985 as its benchmark year, since when the Brazilian currency has been devalued by 13 orders of magnitude.) Next, the industry was in equilibrium in that year, with little or no excess capacity. Finally, and most importantly, detailed data for that year were available from company and independent sources.

The reliability of UVRs at the industry level depends primarily on the coverage of the matched sample (i.e. the share of the output value of matched products in the total industry output) and the variation of UVRs within a sector. The coverage ratio in the larger, more diversified aerospace industry of the USA is obviously expected to be rather low. But for Brazil high coverage rates can be achieved. The most appropriate product match shall thus include a set of products that offers the highest possible coverage ratio for Brazil.

3. Official data, supplementary data and calculations

The ICOP methodology requires manufacturing statistics (on produced quantities and output values) at both product and industry level in the countries compared. The usual sources for such data are economic censuses (carried out typically in a 5-10 year intervals) or manufacturing surveys (annual in non-census years). The *United States Census Bureau* tracks industry output data up to 6 digits in the *Annual Surveys of Manufacturing* (ASM) and up to 10 digits in the *Current Industry Reports* (CIR). The relevant figures for the most detailed classification are however withheld for reasons of confidentiality. Figures are presented only up to 8 digits.

In Brazil, the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics, IBGE) collects data up to the 8-digit level (corresponding to the 10-digit level of the US), but most of the values in the *Pesquisa Industrial Anual* (PIA) are only shown up to 4 digits in the case of the aerospace industry. (The only exception refers to a small share of aircraft parts, amounting to 8% of total output value.)

Officially published figures for the year 2005 for the United States and Brazil are presented in Table 1. The table clearly indicates that the lack of product level data is a major limitation for ICOP-type comparisons. The only comparable figures from the national manufacturing surveys indicate that Brazil produced a total of 8.2 billion BRL worth of aerospace products in 2005, while the United States' production totalled 133,0 billion USD.

Table 1 Industrial Census Information on the Aerospace industry and Commercial Aircrafts (2005)

	Output Quantity (units)	**Gross Value of Output**	**Value Added**	**Unit value**
		(million in national currency)		
United States (USD)				
Aerospace product & parts mfg[a]	n/a	132,977	72,090	n/a
Complete civil aircraft mfg[b]	4,288	27,019	n/a	6.3
Unladen weight not exceeding 2 tons	1,357	458	n/a	0.3
Unladen weight exceeding 2 tons but not exceeding 15 tons	(D)	(D)	n/a	(D)
Unladen weight exceeding 15 tons	(D)	(D)	n/a	(D)
Brazil (BRL)				
Aerospace manufacturing[c]	n/a	8,196	n/a	n/a
Unladen weight not exceeding 2 tons	(D)	(D)	n/a	(D)
Unladen weight exceeding 2 tons but not exceeding 15 tons	(D)	(D)	n/a	(D)
Unladen weight exceeding 15 tons	(D)	(D)	n/a	(D)

Notes: (D) Withheld to avoid disclosing data for individual companies. N/a = not available; a) includes all products of the aerospace industry as specified in NAICS 3364 (see detailed definition in Annex II); b) includes civil aircrafts (fixed wing, powered), helicopters and other civil aircrafts (non-powered) and kits) but excludes aircraft engine.
Sources: a) (NAICS 3364) *Annual Survey of Manufactures 2005*, U.S. Census Bureau; b) (NAICS 33641131) *Current Industry Report M336G(05)-13*, U.S. Census Bureau, Issued: August 2006; c) (CNAE 3531) *Pesquisa Industrial Produto 2005*, vol. 24, No.2., IBGE.

Similar limitations have already been addressed in the ICOP literature. Maddison and Van Ark (1988, pp.114-119) made adjustments for the automobile manufacturing industry based on additional data on the technical specification of products and retail value figures published in industry journals to compare the sector in Brazil, Mexico and the USA. The analogy of cars appears to be appropriate for the aerospace industry. On the one hand, the number of aircraft produced is much smaller than the number of cars, but, on the other hand, the products are much more visible. In other words, while the figures can be concealed in national statistics, it is hard to hide the products physically. We thus looked beyond national statistics and investigated alternative sources: industry journals, industry associations' statistics, independent NGO publications, company statements, or environment reports and accident statistics to locate and cross-check output quantity data and indications of producer prices or retail prices. The additional figures collected and the adjustments made are discussed in the following section.

3.1. Adjustments and calculation of unit value ratios for Brazilian aircraft production

3.1.1. Supplementary data sources

It is nearly impossible to find information on the actual sales price of an aircraft, not to mention producer prices in local currency, especially given the fact that nearly all aircraft produced in 2005 were exported.

In 2005, the only producer (final assembler) of commercial aircraft in Brazil was Embraer. The *Financial Statements for the Years Ended December 31, 2006 and 2005 and Independent Auditors' Report* of the company provides indirect information on the value of aircraft production. The "cost of goods sold" figures (CGS), broken down by commercial/defence/ executive/services segments and presented in BRL in the reports, were used as a proxy for the ex-factory output value of Embraer aircraft for the year 2005. This figure comes closest to the ex-factory value of output. As far as we could ascertain, it does not contain sales taxes and other duties. The figure for cost of goods sold amounted to 6,269 million BRL, which compares realistically to the 8,196 billion BRL value published in the PIA statistics, which also includes other aerospace segments such as helicopters, light aircrafts, aircraft parts and components.

The quantity of physical output of airplanes was obtained from the delivery figures for 2005 published in the *2006 Embraer Annual Report* (p.74). The date of production and the date of delivery of an aircraft may differ, but interviews with company managers and the amount of backlog confirmed that Embraer was producing for direct delivery. (In other words, there were no "white tail" planes in 2005.) The difference between date of production and date of delivery is the testing period following a plane's roll out from the plant, which is not more than a few weeks.

We make the assumption that relative sales prices are proportional to the relative ex-factory prices. Thus, the actual unit value of each type of aircraft can be estimated if the total ex factory value of Embraer aircraft produced and their list prices are known. *Aircraft Value News* (AVN) publishes the list prices of new aircraft in USD (including Embraer as well as Boeing planes) and estimates the prices of used aircraft on a yearly basis. Where this data was not available, data from the *Aviation Industry Group* was used. Aircraft producers sometimes offer significant discounts (up to around 20%, according to industry experts) to customers based on the size of order and delivery arrangements. List prices are thus not the actual selling prices, but they do reflect the value of an aircraft – the larger the demand the closer selling prices will be to the list prices. Given a firm backlog of nearly 500 aircraft for Embraer, the demand can be considered high enough. Where maximum and minimum list prices, were published, we used the average of maximum and minimum prices.[7] The second and third column of Table 2 presents the data collected in this fashion.

Table 2 Supplementary Data on list prices and output value of commercial aircraft produced in Brazil (2005)

Aircraft type (1)	**Quantity of Output** (2)	**Average list price (USD millions)** (3)	**Unit values (BRL millions)** (4)	**Output Value (BRL millions)** (5)
ERJ-135	2	16.1	28.1	56.1
ERJ-140	0	n/a	n/a	0
ERJ-145[a]	67	22.2	38.7	2592.8
ERJ-170	46	27.5	47.9	2205.1
ERJ-175	14	29.6	51.6	722.4
ERJ-190	12	33.1	57.7	692.4
ERJ-195	0	34.9	60.8	0
Total	141		44.1	6,269

Source: Col. 2 from *Embraer 2006 Annual Report*; Col. 3 from *Aircraft Value News* and *Aviation Industry Group*, Total Col. 5 from Embraer; Col. 4 and the rows of Col 5 except total, own calculations as described in main text section 3.2.1.

Note: (a) ERJ-145s also include modified versions of the aircraft: 20 Legacy executive jets and an R-99A sold for the Brazilian government.

3.2.1. Unit value ratios

The final step of data preparation before unit value ratios can be calculated is the estimation of unit values of aircraft produced in the two countries. Based on the assumption that relative list prices indicate relative ex-factory unit values of an aircraft, we derived unit values in Brazilian Reais from the list prices in US dollars, according to equation (1) below. The resulting unit values are reproduced in column 4 of Table 2.

$$uv_i^{BRL} = \left(\frac{lp_i^{USD} q_i}{\sum lp_i^{USD} q_i} \cdot CGS^{BRL} \right) \Big/ q_i \quad = \quad lp_i^{USD} \cdot \frac{CGS^{BRL}}{\sum lp_i^{USD} q_i} \qquad (1)$$

[7] List prices were not available for the Legacy executive jets, since they are primarily sold individually. We assumed that additional, tailor-made design features make the Legacy jets fit more appropriately in the ERJ-145 category, even if their size is more similar to the ERJ-135s, (Should they be categorised as ERJ-135s, only the output value shares change, the effect on the final results is within 2%.)

Where uv_i = unit value of an aircraft type in year 2005
lp_i = list price of an aircraft type in year 2005 in USD
GVO = total value of output in year 2005
CGS = costs of goods sold in the commercial segment, proxy for GVO^{BRL}

The gross output values in column 5 of Table 2 are calculated by multiplying numbers of planes with the unit values in column 4.

3.2. Adjustments and calculation of unit value ratios for production in the United States

3.2.1. Supplementary data sources

The *Aerospace Industries Association* (AIA) of the US collects and publishes a rich set of statistics that include yearly production data of civil transport aircraft[8] by type, including physical output quantity and aggregate value. According to AIA figures, the total value of civil jet transport aircraft (or airliner) production in 2005 was 18.7 billion USD (see Table 3). This amounts to some 70% of the 27.0 billion USD output value presented in the *Current Industry Report* (CIR) for 2005. The difference is explained by the fact that the CIR includes not only airliners, but light and general aviation aircraft that fall in the less than 2 ton and the 2-15 ton class category, as well as helicopters and other (non-powered) aircraft.

Neither AIA, nor other sources publish price or unit value data for specific aircraft types. Assuming once again that the proportions of list prices are identical to proportions of ex-factory unit values, we used list prices of US airplanes published in AVN to estimate ex factory unit values, as in the case of Brazil.

The first row of Table 3 shows the aggregate quantity and value data for all aircraft from the CIR, the bottom row the quantity and value data for narrow and wide bodied aircraft. Produced quantities of the various aircraft types as published by *AIA*, together with the list price information as reported in AVN are shown in the second and fourth column of the table. By 2005, B-717s and 757s are no longer included in the list prices for newly produced planes. The latest quotations from 2004 and 2002, respectively, have been used to price these models. Of the narrow-body aircraft, the B-717 and 757 families only included one model each (the 717-200 and the 757-300). The 737 family however varies considerably in size, so the quantities for the Boeing 737-600, 700, 800 and 900 series were additionally obtained directly from the manufacturer.

[8] A substantial part of the U.S. industry output consists of military aircraft that we do not include in this study, considering that there is no Brazilian product to match them. This fact is expected to result in a lower coverage ratio of matched products in the total U.S. output.

3.2.2. Calculating unit values of Boeings

Ex-factory unit values of the various types were calculated for Boeings in the same way as described above in the case of Brazil, the only difference was that total gross output value of the 290 commercial aircraft was directly available. Based on the assumption that relative list prices indicate relative ex-factory unit values of an aircraft, we derived unit values in US dollars from the list prices in US dollars, according to equation (2).

$$uv_i = \left(\frac{lp_i^{USD} q_i}{\sum lp_i^{USD} q_i} \cdot GVO^{USD} \right) \Big/ q_i \; = \; lp_i \frac{\sum uv_i q_i}{\sum lp_i q_i} = lp_i \frac{GVO}{\sum lp_i q_i} \qquad (2)$$

Where uv_i = unit value of an aircraft type
lp_i = average list price of an aircraft type
GVO = Gross value of output for all aircraft
q_i = produced quantity of an aircraft type

The obtained unit values of the aircraft types produced in 2005 are shown in the fourth column of Table 3. Our estimates of ex-factory prices are 71% of average list prices. On a side note, it is interesting to see that even if producers offer a 20% discount, they still retain a margin over the ex-factory price. Gross output values for different types of aircraft were obtained by multiplying the quantities with our estimated unit values. The quantities are reproduced in column 2 of Table 3.

Some further steps are required before Brazilian and US-produced aircraft can be compared. In the comparison, the difference in aircraft size is striking. It is not realistic to match Brazilian regional jets with US jumbo jets. The difference is less pronounced if we compare the Brazilian planes with the smaller Boeing aircraft. On the US side, we therefore distinguished between wide-bodies and narrow-bodies. Narrow-bodies are aircraft with an average seating capacity of 130-150 and an average range of 4,500 kilometres are normally used for interregional as well as regional travel and compose the bulk of airliners sold. Wide-bodies are the workhorses of long-range, intercontinental air transportation and as our estimated unit values show their average unit values are about 100 million dollars higher than narrow-bodies. These jets can most likely be excluded from any potential product matching since no emerging country has so far been able to produce series of this category.

The average unit value for the narrow-body class was 43.3 million dollars; its total produced value was 9,839 million dollars in 2005. (The Boeing 737 family is evidently the most representative of this class.)

Table 3 Supplementary Data on List Prices and Output Value of Aircraft Produced in the United States (2005)

Aircraft type	Quantity of Output	Average List Price (USD Millions)	Unit values (USD millions)	Total output value (USD millions)
(1)	(2)	(3)	(4)	(5)
Civilian Aircrafts Manufacturing[a]	4,288		6.3	27,018
Narrow-bodies	227		43.3	9,839
B-717	13	40.0[b]	28.3	368
B-737	212	61.4	43.4	9,202
-600	*3*	*49.5*	*35.0*	*105*
-700	*98*	*56.5*	*39.9*	*3,914*
-800	*105*	*67.8*	*47.9*	*5,032*
-900	*6*	*71.8*	*50.8*	*305*
B-757	2	81.4[c]	57.5	115
Wide-bodies	63		141.2	8,897
B-747	13	221.8	156.8	2,038
B-767	10	135.5	95.8	958
B-777	40	208.7	147.5	5,901
Total	290		64.6	18,736

Notes: (a) includes all civilian aircraft and helicopters produced; (b) list prices of 2004; (c) list prices of 2002.
Sources: First row and row total from: Current Industry Report, U.S. Census Bureau, August 2006; Columns 2 and 4 from Aerospace Industries Association (2008) (a) and *Aircraft Value News*, 2005 (and 2004) Quantities of B-737 series from Boeing Online Query for Orders and Deliveries, URL: http://active.boeing.com/commercial/orders/index.cfm?content=userdefinedselection.cfm&pageid=m15527 (retrieved: 12 September 2008) Columns 5 and 3: Own calculations as described in main text

3.3. Product matching and calculating UVRs

A key reason of Embraer's success was entering the market niche for regional aircraft. However, as discussed above, this poses significant challenges when it comes to comparing its production with producers in the larger segments. The ICOP methodology suggests that once the product unit values are available, UVRs can be calculated by matching products based on "broadly defined classes". The fact that aircraft size differs in the two countries calls for caution but is not considered an impediment as long as similar product characteristics can be used for classification. Bart van Ark and Hans Gersbach (1994) have addressed a somewhat similar problem that could be triggered by high-tech products that either have different product descriptions in the two countries; where (possibly due to issues of confidentiality) no information is available on value or quantity of production; are unique to one country; or where there is a different product mix in the industry. Following their suggestion, we looked for additional industry data to obtain the best matches – data on the technical specifications of aircraft. Based on such features, we have looked into possible alternatives of matching to achieve the highest possible number of products included.

Two possible dimensions for matching are plane size (wide bodied, narrow bodied, or number of seats) or plane weight. International trade and production statistics distinguishes airplanes weighing less than 2 tons, between 2-15 tons and more than 15 tons (unladen).[9]

Size is a better criterion for matching than weight. Most Brazilian-made jetliners fall in the category of 2-15 tons, close to the upper limit, with only the largest ones of the E-170/90 family weighting more than 15 tons. On the other hand, all US-produced planes weigh more than 15 tons. The best purely weight-based match would only involve two products: the Brazilian ERJ-190 jets and the US B-717.

There are several reasons why we choose not to limit matching to these products. First, the product match would only include 13 out of the 290 planes produced in the USA. and 13 out of the 142 planes produced in Brazil. Moreover, the significance of this product match is questionable since the B-717s are the last planes of an outgoing model (in fact, it is just a new name given to the old MD-95s after Boeing acquired McDonnell Douglas), while the ERJ-190s are the first of a new series of planes. The prices and values of these non-representative items may well be biased. Thirdly, weight-based approaches have the shortcoming that they do not necessarily reflect the technological sophistication of a product. Producers often cut costs with the use of stretched versions of aircrafts with the same technologies involved, same avionics and highly similar aerodynamic features and most importantly, with interchangeable parts and components.[10] Furthermore, with the use of advanced light materials (composites), more sophisticated planes are not necessary heavier than their smaller, older counterparts.

Body breadth classifications distinguish between narrow-body (single-aisle) and wide-body aircraft. This feature turned out to be useful for matching because it creates a clear distinction between long-haul jets and the short- to medium-haul ones that require different production capacities and differ in durability. (Even if a few of the narrow-body category planes can be fitted for long-range operations, they represent a very small share of the output in both countries.) We therefore matched Brazilian narrow body aircraft with US narrow body aircraft.

The body breadth classification is useful, since it also provides a solution to the weight delimitation issue by setting the boundary at 64 tons (or 45 tons without the B-757s). (All Embraer jets have single aisle; see Table 3 for Boeing single-aisles). Narrow-bodies cover 76% of Brazilian aerospace industry output compared to 8% in the United States. This is not surprising, since the Brazilian industry is specialized in the manufacturing of commercial jets while the United States output is far more diverse and consists of a whole range of other products including military aircraft, engines, missiles and space vehicles – as well as parts and components for Brazilian planes.

[9] See e.g. SITC Rev.3 codes 792.2., -3 and -4.

[10] See e.g. aircraft families such as New Generation Boeing 737s, where operational empty weights vary between 36.3 and 45.4 tons (with the -600 and -800 respectively)

3.4. Comparing small apples with big apples: adjustments for product size differences

Even when jumbos and other wide-body jets are excluded from direct product comparison, regional jets of Embraer and single-aisles planes of Boeing differ significantly in number of seats. Given these differences, we followed two alternative ways to calculate the unit value ratio. (1) First, we directly matched the two groups of narrow-body jetliners, disregarding differences in size. The rationale behind this approach is to compare actual products, without any modification of the figures. As the planes produced in the United States are larger than in Brazil, Brazilian output will be overestimated and US output will be underestimated. (2) The second alternative is to standardize all the narrow-body commercial aircraft produced in the two countries to 100-seat equivalents and then make a product match. In this way, size differences are taken into consideration. But as the quality differences between smaller and larger single aisle airplanes are likely to be smaller than indicated by the number of seats, Brazilian output will tend to be underestimated relative to US output. There is a substantial difference between the unit value ratios calculated according to these two approaches. We decided to take the geometric average of the standardised and non-standardised estimates.[11]

The plausibility of our results can be checked by comparing them with the results Mulder *et al* (2002) as well as with the relative "sales price level" which refers to the relative list prices of standardized aircraft.

3.4.1. Standardization

Standardizing is a solution to eliminate the size differences across the products of the two countries. We looked at two attributes: operational empty weight (OEW) and maximum number of seats of the single-aisles jets[12] manufactured in 2005. The correlation with unit values was high in both instances, but the number of seats showed marginally higher correlation with the unit values than weight (0.98 vs. 0.96 for the combined data of both countries). As discussed above, seating capacity is the most meaningful criterion for standardization. For practical reasons, we chose to standardise planes at 100 seats, which is less than the US average and more than the Brazilian. The choice of number of seats over OEW or other technical characteristics as a proxy for value of an aircraft is also supported in the airplanes marketing literature (see Ferreri, 2003, p.219).

There are two ways to obtain unit values for the 100 seat equivalent (100SE) jets. First, assuming that the size ratio of an actual plane compared to 100SE equals the seating capacity ratio (i.e. a Boeing 717 with 117 seats is 1.17 x 100SE), the produced quantity of 100SEs can be calculated for both countries. The

[11] As there is only a single large product match, there is no need to calculate a Paasche and a Laspeyres unit value ratio (see annex I).

[12] Includes the single-aisles jets manufactured in the year 2005, B717, B737-600, -700, -800 and -900, but excludes the B757-200s as outlier.

unit values of the 100SEs are then calculated by dividing the (unchanged) total value of ex-factory output by the modified total quantity of production of narrow-bodies.

Alternatively, the association between seating capacity and unit value of a plane can also be the basis for obtaining unit values of the 100SE using a simple kind of hedonic regression. We estimated a linear function to predict the unit value of the 100SE and then calculated the quantity of 100 SE planes produced by dividing the unit value into the total value of ex-factory output. The two methods rendered somewhat different results, reproduced in tables 5 and 6. Since the regression method makes more optimal use of all information, we used the regression method for standardising output. The calculations (for both methods) are presented below in greater detail.

The adjusted quantity figures for the USA are shown in column 3 of Table 4. Since the average seating capacity grew by two-third after the standardization, the unit value of the narrow-bodies category decreased by some 40% from 43.3 to 25.8 million USD.

Following the seat-based hedonic regression method, equation (3) estimates a unit value of the 100SE of 26.5 million USD reproduced in column 6.

$$uv = 0.233 * seats + 3.19; R^2 = 0.97 \quad (3)$$

$$uv\ (100SE) = 26.5\ m\ USD;$$

$$Q\ (100SE) = 9839/26.5 = 371.0\ m\ USD$$

Table 4 Results of Quantity and Unit Value Adjustments for the Production of 100-Seat Equivalent Aircraft (100SE) in the USA

Aircraft type	Maximum seating	Produced quantity	Simple re-weighted output quantity of 100SE	Unit value of 100SE	Re-weighted output quantity of 100SE (hedonic)	Unit value of 100SE (hedonic)
	(1)	(2)	(3)	(4)	(5)	(6)
B717	117	13	15.2			
B737-600	132	3	4.0			
B737-700	149	98	146.0			
B737-800	189	105	198.5			
B737-900	215	6	12.9			
B757	228	2	4.6			
Total		227	381.1	25.8	371	26.5

Source: as described in text

Applying the first method for Brazil reduces the total production quantity from 142 to 87.6 planes and increases the unit value from 44.1 to 71.5 million BRL (see Table 5). The difference is smaller if the second method is used according to equation (4), which predicts a unit value of 62.1 million BRL for the standardized 100-seater aircraft and a standardised number of 101 planes.

$$uv = 0.478 * seats + 12.95; R^2 = 0.97 \quad (4)$$

$$uv\ (100SE) = 60.8\ m\ BRL;$$

$$Q\ (100SE) = 6269/60.8 = 103.2\ m\ BRL$$

Table 5 Results of Quantity and Unit Value Adjustments for the Production of 100-seat equivalent Aircraft (100SE) in Brazil

Aircraft type	Maximum seating	Produced quantity	Simple re-weighted output quantity of 100SE	Unit value of 100SE	Re-weighted output quantity of 100SE (hedonic)	Unit value of 100SE (hedonic)
	(1)	(2)	(3)	(4)	(5)	(6)
ERJ-135	37	2	0.7			
ERJ-145	50	67	33.5			
ERJ-170	70	46	32.2			
ERJ-175	78	14	10.9			
ERJ-190	98	12	11.8			
Total		141	89.1	70.3	103.2	60.8

Source: as described in text

3.4.2. The unit value for narrow-bodies

First we directly matched the two groups of single-aisles aircraft produced in the two countries. This resulted in a unit value of 1.03 reproduced in the first row of Table 6. This value is lower than the official exchange rate of 2.43 Reais to the US dollar for 2005). This means that using the exchange rate would lead to an undervaluation of Brazilian aerospace manufacturing output.

Matching standardized 100SE planes results in a much higher unit value ratio of 2.29 BRL/USD according to the hedonic method (and 2.72 if one would choose the simple method), as shown in Table 6.

There is a large difference between the unit value ratios derived by matching standardized and non-standardized aircraft. The unit value ratio for the non-standardised match is far below the exchange rate, the unit value for the hedonic match is only slightly lower than the exchange rate. As explained above, we decided to take the geometric average of the non-standardised and hedonic standardised matches, as both have bias in an opposite direction. The geometric average of the two UVRs is 1.54 BRL/USD.

Table 6 Brazil-USA Product Matching for Calculating Unit Value Ratios

	Brazil					USA					Unit Value Ratios
method	Product	Q(BRA)	V(USD)	uv(USD)	Q(BRA) @USA uvs	Type	Q(USA)	V(USD)	uv(USD)	Q(USA) @BRA uvs	
1.	Embraer narrow-bodies	141	6,269	44.5	6,111	Boeing narrow-bodies	227	9,839	43.3	10,092	1.03
2/a	Embraer – 100SE	89.1	6,269	70.3	2,301	Boeing - 100seater	381.1	9,839	25.8	26,807	2.72
2/b	Embraer – 100SE	103.2	6,269	60.8	2,736	Boeing - 100seater	371.0	9,839	26.5	22,546	2.29
	Geometric average of 1 & 2/b:										1.53
	Exchange rate										2.45
	Updated UVR for transport equipment industry, based on Mulder *et al* (2002)										1.94

Notes: 100SE stands for 100-seat equivalent;
Method 1 refers to the direct matching of Brazilian and US-made narrow body aircraft;
Method 2a refers to matching standardized 100SE planes on the basis of seat numbers
Method 2b refers to matching standardize 100Se planes on the basis of a hedonic regression (see section 3.2.1).

3.5. Comparisons with other UVR estimates

The official exchange rate for 2005 averaged 2.45 BRL to a dollar.[13] Thus our preferred UVR estimate of 1.53 BRL/USD is well below the exchange rate. The study of Mulder *et al* (2002, Table 3, p.13) comparing Brazil with the USA presents unit value ratios for 18 manufacturing branches, including transport equipment for the benchmark year 1985. Their unit value ratio for the transport equipment sector in 1985 was 2,689 BRZ/USD. This unit value ratio is based on 7 product matches covering 56.3% of Brazilian output and 25.4% of US output. The coefficient of variation of the UVRs within the branch was low[14] (*ibid*, Table 3, p.13). We updated the 1985 UVR to 2005, using price indices from both countries.[15] This resulted in a UVR of 1.94 BRL/USD, which is still below the official exchange rate, but 26% higher than our 2005 UVR of the aerospace industry of 1.53 BRL/USD. Such a difference seems reasonable, given that almost all of the aerospace products are intended for export, while a greater share of other transport equipments, including cars, serves the domestic market. Though not identical, the two estimates are clearly in the same ballpark.

[13] Annual average BRL/USD exchange rate for 2005 (IMF)

[14] Coefficients of variation indicate to the reliability of the aggregate ratios as they refer to the homogeneity of the product UVRs in a branch. Its value increases with the coverage ratio. The ICOP literature considers variations below 0.1 reliable, which is clearly the case of this industry with a variation of 0.01 if Brazilian quantity weights and 0.0 if US weights are applied.

[15] We applied an industry level wholesale price index for Brazil from FGV ($3.64*10^{-10}$) and industry level producer price index for the USA from BEA (0.72), and accounted for the currency devaluation in Brazil (($1/(2.75*10^{12})$)).

4. Productivity Comparisons

Consistent published series of value added and employment in aerospace manufacturing are not available. Our time series for the two countries have been constructed from a variety of sources (see Vertesy, forthcoming, Chapter 2). For Brazil, official gross value of output (GVO), value added (VA) and employment figures are available from IBGE from 1996 onwards. Value added time series were extrapolated backwards in time, using the index of total sales values of Embraer and the ratios of value added to gross output from IBGE for the transport equipment industry, as follows. First, the gross value of output was extrapolated from 1996 to 1970 using a index of total sales values of Embraer[16]. Subsequently, value added output ratios for the total transport equipment industry were applied to estimate the VA series. The data collected by the *Aerospace Industry Association of Brazil* (AIAB) were used for the employment series between 1986 and 1995. The employment level of 1986 has been extrapolated back to 1973 based on the time series of Embraer's labour force for the years 1973-1985 from Cabral (1987).

For the USA, our value added series combines figures from the EU KLEMS (SIC based, 1970-84) and the OECD STructural ANalysis Database (STAN) (1985-2006) database; the value of 2007 is derived from the value for 2006 from STAN by applying the 2006-2007 index from the Annual Survey of Manufacturing. The employment series combine the following sources: the Groningen Growth and Development Centre's 60 industry database (1970-1980), UNIDO Industrial Statistics (1981-1990), the OECD's (STAN) for 1991-2006; this was extrapolated to 2007 using the employment index from the Annual Survey of Manufacturing.

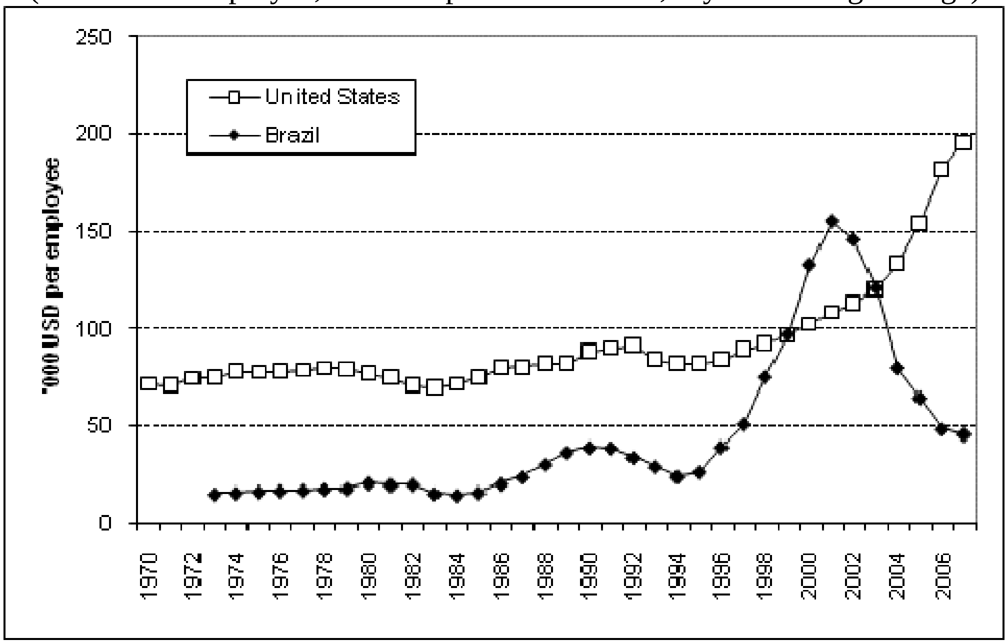
The trends in labour productivity in the aerospace industry in Brazil and the United States are charted in Figure 3. Labour productivity series were calculated by dividing value added at constant prices with number of employees. The benchmark productivity comparison for 2005 has been extrapolated using constant price time series of the two countries.

The study by Mulder *et al* (2002, Fig.4, p.19) showed that the Brazilian transport equipment sector was outperforming other Brazilian manufacturing sectors, with a significant productivity lead from 1987 onwards. It was the only sector which attained the productivity levels of the USA (from 1996 to 2002). But they make cautionary remarks about the reliability of Brazilian time series (*ibid*, p.20).

[16] sales values in USD for 1970-82 from Ramamurti, 1986, Table 5.5, p.193; 1983-84 from Cabral, 1987; 1985-91 Frischtak, 1992; and 1992-96 Embraer Annual Reports; World Bank WDI GDP deflators were applied

Figure 3 Comparative Labour Productivity Trends in Aerospace in Brazil and the USA, 1970-2007

(1000 USD/Employee; constant prices 2000=100, 3-year moving average)

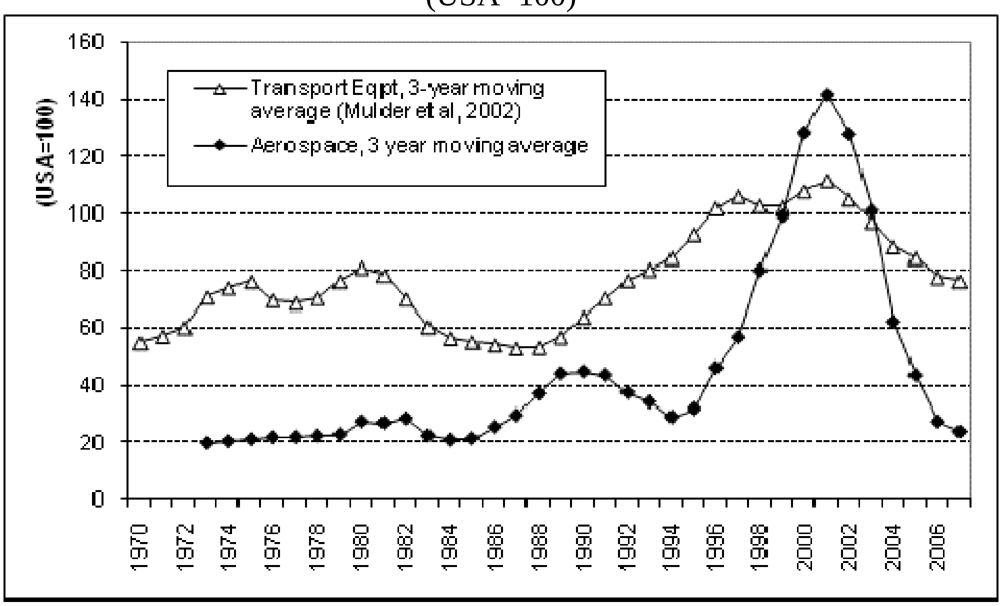


Sources: see text.

Note: actual figures, including value added and employee data are shown in Annex III.1

Figure 4 Comparison of Labour Productivity Levels in Transport Equipment and Aerospace, Brazil/USA, 1970-2007

(USA=100)



Sources: Transport equipment manufacturing industry figures from Mulder *et al*, (2002, Fig,4, p.19), updated with recent data from IBGE after 1999; aerospace industry values from own calculations.

Note: actual figures are available in Annex III.1

Our study indicates that the Brazilian aerospace industry was not performing as well as the transport equipment sector as a whole before the late 1990s. Except for a peak reached in 1989, labour productivity of the aerospace sector was on average half the levels of the aggregate transport branch (Figure 4). However, from the mid-1990s onwards, the aerospace industry experienced more rapid productivity growth that resulted in its overtaking the transport equipment manufacturing branch between 2000 and 03.[17]

In an international comparison with the US aerospace industry, Brazilian productivity exceeded the level of the US between 1999 and 2003. In 2001 and 2002 labour productivity exceeded the US level by no less than 40 per cent., before suddenly collapsing to around 20 percent in 2007 (Figure 4).

The US productivity trend shows much more stability over time than that of Brazil, with a rapid growth spurt during the last decade as result of consolidation in the sector. Productivity growth in Brazil is marked by fluctuations, with value added per employee varying between 12 and 176 thousand dollars per worker. Given that series production and foreign sales of Brazilian commercial aircraft only started in 1970, it is no surprise that for the first two decades, the newly emerging industry remained less productive than its US counterpart. The relatively low value added levels were related to Embraer's strategy of acquiring foreign technology (see Cassiolato *et al*, 2002, pp.9-10). There are two significant downturns: between 1990 and 1994 and after 2002. The productivity decline in the early 1990s is related to the crisis in the aerospace industry (see Frischtak, 1992 and Vertesy, 2010, Chapter 5, forthcoming). Value added declined from a peak value of 560 million USD in 1989 to 130 million in 1994. This was only partly offset by the decrease in employment from 13,700 to 6,900 persons. The productivity growth in the subsequent period was achieved by steep increases in value added, followed by increases in the labour force at a much slower pace. However, the number of employees continued to grow steadily even when value added started to decline in 2003, due to the fact that Embraer repositioned itself as a system integrator importing over 90% of its aircraft parts and components from overseas (see Figueiredo *et al*, 2008). This resulted in a very sharp drop in productivity, by some 180 thousand dollars per employee.

4.1 Firms' Dramatic Miscalculations

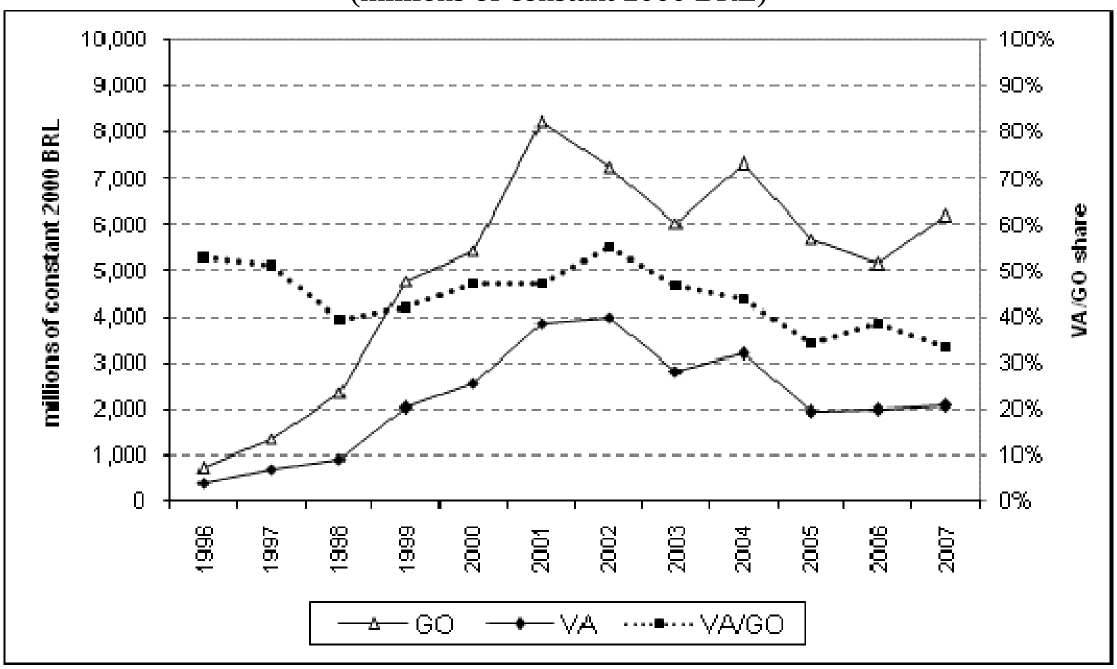
The dramatic drop in labour productivity since 2001 is so striking that it calls for a careful analysis of the changes in the underlying value added and employment trends. The changes in the share of value added in gross output in the Brazilian aerospace industry are shown in Figure 5. In 1998 value added amounted to 39% of total output, but over the next four years its share increased to 55%. (In comparison, this ratio for

[17] We have extrapolated the transport equipment series of Mulder *et al* (2002, Fig.4, p.19) from 1999 onwards using updated value added and employment series from the same sources (IBGE for Brazil and BEA for the USA).

the entire Brazilian manufacturing industry remains constantly around 45% (Unicamp, 2008, Fig.6, p15).) The period between 1998 and 2002 is characterized by two opposing forces. Embraer witnessed the success of its E-135/145 family, which contained parts and components overwhelmingly manufactured abroad. The company retained design, assembly and marketing activities and increased competitiveness. A Unicamp study on the sector (Unicamp, 2008) explains the fact that value added grew at a faster pace than gross output by the business cycle effect. The success of the ERJ-135/145 family strengthened the local supply chain; new small businesses were formed, mainly by former employees of Embraer (the number of enterprises in the sector grew from 76 in 1996 to 111 in 2002).

Figure 5 Gross output and value added in the Brazilian aerospace industry, Brazil (1996-2002)

(millions of constant 2000 BRL)



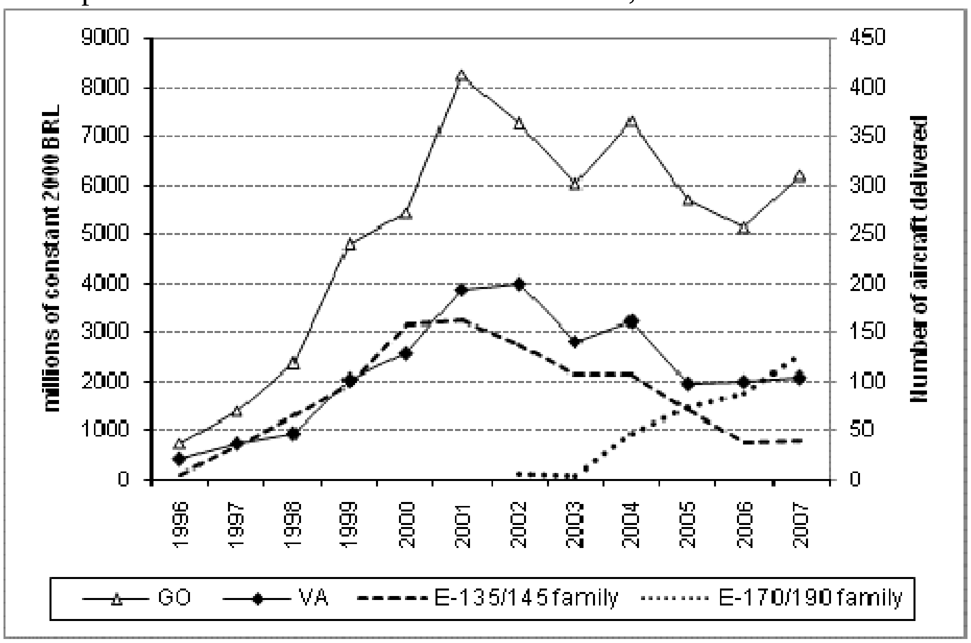
Sources: IBGE, FGV

Note: GO = Gross Output; VA = Value Added; SA = Sales. FGV transport sector deflators applied. Actual figures are available in Annex III.2.

Between 2002 and 2005 industry value added declined by more than 50% while gross output only declined by 20%, resulting in a decline of the value add/output ratio to around 33 per cent. The reason for these changes has to do with changes in the structure of production. Figure 6 illustrates that the peak in value added between 1999 and 2003 is associated with the production cycle of the E-135/145 family of regional jets. Since the development costs of the E-170/190 family were expected to be nearly 3 times as high as that of the E-135/145 family, estimated to be around 300 million USD in 2002 (Goldstein, 2002b), Embraer decided to rely more heavily on foreign risk sharing partners. This resulted in a decline in the local content of the aircraft produced. Despite the fact that Embraer required foreign components suppliers to transfer at least a small share of production to Brazil, value added did not increase when the E-170/190 jets' production cycle took off.

Figure 6 The production cycle of the E-135/145 and E-170/190 families and gross output and value added in the Brazilian aerospace industry

(Gross output and value added in constant 2000 BRL; number of deliveries in units)



Sources: IBGE, *Airlinerlist* database

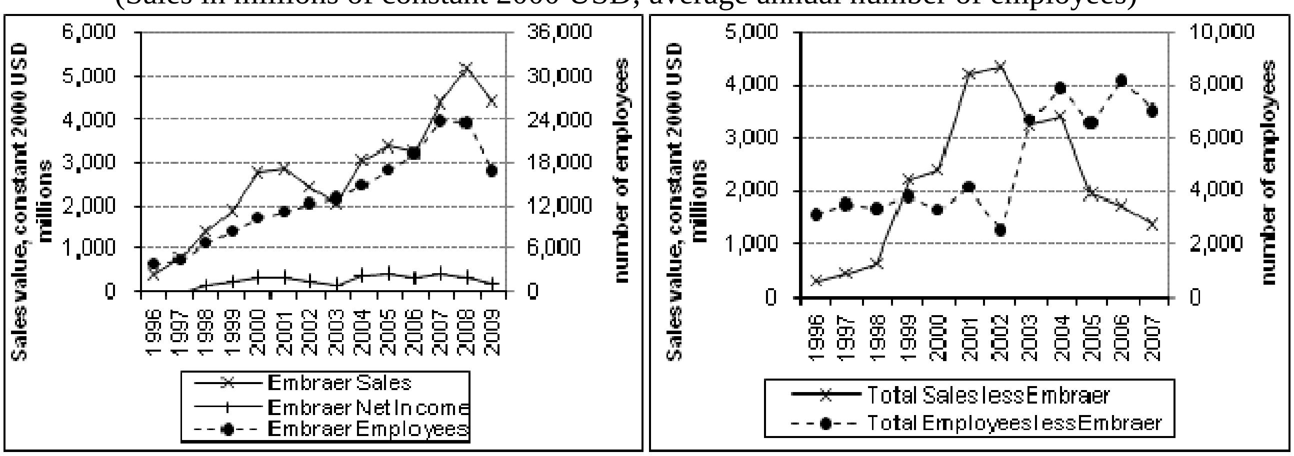
The more than twofold increase in employment between 2002 and 2007 is even more puzzling in light of the decrease in value added during the same period. Firms need to cover wages and profits from their value added. The fact that over this period total employment increased by 110% and total wages increased by 60% while value added decreased by 50% and total sales decreased by 10% indicates that – if the statistics are correct – the firms behaved in a rather irrational fashion.

We can distinguish the performance of Embraer from the rest of the industry. Embraer nearly doubled its labour force from 12,227 in 2002 to 23,734 in 2007. At the same time, its sales increased by 80% and its net income increased by 90% (see Annex III.2). The net income per employee figures may be more meaningful to show the investment or increasing cost of human resources. These values averaged at nearly 30 thousand USD at the peak of 1999-2001 and abruptly plummeted to as low as 10 thousand in 2003. As the successful launch of the E-170/190 jets secured a profit growth in 2004, net income per employee grew rapidly to 24 thousand USD in a year, justifying Embraer's investment in employees in order to meet the increased demand and reduce the backlog. Although profits continued to rise until 2007, the continued job increase was disproportionate, resulting in a steady decline of net income per employees to 17 thousand USD. (The decline continued until 2009 to 12 thousand USD, even after the labour force, mostly production workers, was reduced by nearly 30% as a response to the falling demand caused by the global financial crisis.)

The employment trend in the rest of the industry, primarily the local suppliers of Embraer, appears even more puzzling. The right panel of Figure 7 shows the major increase in employment between 2002 and 2003. Between 1996 and 2002 the industry excluding Embraer employed on average 3,400 persons, after 2003 the labour force averaged 7,200 persons. It is interesting to see that the nearly 7-fold sales increase of these local suppliers between 1998 and 2002 was not accompanied by a similar increase in employment. Employment started to increase in 2003 (a nearly 3-fold increase from 2002 to 2004), just when sales started to shrink. Employment stabilized at a high level, while sales continued to decline. By 2007 they were 60% lower than in 2004. Part of the explanation may lie in the rigidity of labour laws in Brazil that make job cuts rather costly for companies.[18]

Figure 7 Sales and Employees of Embraer (1996-2009) and in the industry without Embraer (1996-2007)

(Sales in millions of constant 2000 USD; average annual number of employees)



Sources: IBGE, Embraer.
Note: Actual figures are available in Annex III.2.

The increases in the number of employees may to some extent originate in government policies (at the municipal, state and federal levels) aiming to strengthen the sector and the Embraer Programme for the Expansion of the Brazilian Aerospace Industry (PEIAB) (for details, see Cassiolato *et al*, 2002, p.47). As a result, new foreign investment came to the Sao Jose dos Campos cluster, e.g. by Latecoere, Sonaca (Sobraer), Liebherr (ELEB). The PEIAB team estimated that the number of new jobs associated with the

[18] When in 2009 Embraer announced what looked like a 20% job cut as a response to the global financial crisis, trade unions as well as the federal government were both trying to block the move. The labour court however approved the dismissals if Embraer was paying the required compensation ("Embraer comes to terms with job cuts" *Financial Times*, 2 June 2009).

new industrial policy was less than 2000 (Cassiolato *et al*, 2002, p.50). Thus, even if the expected increase in employment was fully realised, this can hardly account for the overall increase of employment in 2003 by more than 4000 persons.

Another explanation of these puzzling phenomena may have to do with the lack of data on hours worked. Employment figures in this study refer to annual average number of persons employed. Full-time equivalent values are unfortunately not available. Assuming that the growth period of 1999-2002 was characterized by excessive overtime work, which was subsequently reduced in 2003 by hiring more employees might explain some of the peculiarities of the employment trend. The observed labour productivity decline may be exaggerated. But this explains at best part of the trend. The fact remains that employment is inflexible vis-à-vis the decline of sales and value added.

There are also structural explanations for the significant fluctuations in labour productivity in the aerospace industry in Brazil. The upswings during the late 1980s and the 1990s coincide with a significant change in the composition of the labour force, brought about by advances in computer aided design and other technological transformations that resulted in the downsizing of the blue-collar workforce and requiring very different knowledge and skills on the part of engineers.

However, there continues to be a number of institutional factors that work against the sustained growth of productivity. In an interview, the founder and long-time director of Embraer, Ozires Silva, highlighted that "the Brazilian cost" of bureaucracy and taxes significantly decrease the efficiency of producing in Brazil, requiring "20 people in Brazil for the job of 3-5 in the US".[19] Thus, even if aerospace engineers in Brazil have acquired skills and competences that are globally competitive, long-term productivity growth in the industry depends to a great extent on the relaxation of institutional constraints.

[19] Interview with Ozires Silva, Sao Paolo, 6 Apr 2009.

5. Conclusion

The Brazilian aerospace sector is often seen as one of the star performers in latecomer economies. In this paper, we have for the first time succeeded in calculating a US/Brazil conversion factor, specific to the aerospace industry. The ICOP methodology has informed the approach; However, the lack of officially published statistical data could only be overcome by consulting a variety of alternative sources, including company financial reports, industry association data and data collected by "independent enthusiasts". With such data at hand, the focus on a single industry allowed us to pay special attention to product characteristics in the product matching procedures. Our resulting UVRs for the benchmark year 2005 proved to be somewhat lower than, but not inconsistent with the extrapolated 1985 UVRs for the transport equipment manufacturing industry from Mulder *et al.* (2002).

Applying the UVRs in order to compare labour productivity levels and trends in Brazil and the USA provides us with interesting insights in Brazil's comparative productivity performance. The rapid growth in the 1980s resulted in a first catch-up episode from 1985 to 1990 that came to an end during the crisis years of the Brazilian aircraft industry in the mid-nineties. The late 1990s brought a second and more rapid productivity spurt that resulted in Brazil temporarily overtaking the USA. However this productivity growth proved to be a bubble that burst after 2002. The industry as a whole, and especially the subcontracting segment, appears to have been oblivious to the economic realities of a declining value added. Firms continued to increase the number of jobs for over five years. The result was a rapid and deep drop in productivity, both in absolute terms and in comparison with to the USA.

References:

ABDI and UNICAMP. 2008. “Industria Aeronautica, Volume I.”, (project leader: Barbieri, Marcos) *Relatório de Acompanhamento Setorial*, Marco 2008.

Ark, Bart van. 1993. "International Comparison of Output and Productivity." *Monograph series no. 1*. Groningen Growth and Development Centre: Groningen.

Ark, Bart van and Hans Gersbach. 1994. "Micro Foundations for International Productivity Comparisons." *Research Memorandum, GD-11*. Groningen Growth and Development Centre: Groningen.

Cabral, Arnoldo Souza. 1987. "Análise do desempenho tecnológico da industria aeronautica brasileira." PhD dissertation, ITA: Sao Jose dos Campos.

Cassiolato, Jose E, Roberto Bernardes, and Helena Lastres. 2002. "Transfer of Technology for Successful Integration into the Global Economy: A case study of Embraer in Brazil." 64. UNCTAD and UNDP: New York and Geneva.

Dijk, Michiel van. 2002. "South African Manufacturing Performance in International Perspective, 1970-1999." *Research Memorandum GD-58*. Groningen Growth and Development Centre: Groningen.

Ferreri, Domenico. 2003. *Marketing and management in the high-technology sector: strategies and tactics in the commercial airplane industry*. Westport, CT; London: Praeger.

Figueiredo, Paulo, Gutenberg Silveira, and Roberto Sbragia. 2008. "Risk Sharing Partnerships With Suppliers: The Case of EMBRAER." *Journal of Technology Management and Innovation*, 3:1, pp. 27-37.

Frischtak, Claudio R. 1992. "Learning, Technical Progress and Competitiveness in The Commuter Aircraft Industry: An Analysis of Embraer." *Industry Series Paper*. The World Bank: Washington, D.C.

Goldstein, Andrea E. 2002a. "The political economy of high-tech industries in developing countries: aerospace in Brazil, Indonesia and South Africa." *Cambridge Journal of Economics*, 26:4, pp. 521.

Goldstein, Andrea E. 2002b. "EMBRAER: From national Champion to global player." *Cepal Review*: 77, pp. pp. 97-115.

Goldstein, Andrea E. and Steven M. McGuire. 2004. "The Political Economy of Strategic Trade Policy and the Brazil-Canada Export Subsidies Saga." *World Economy*, 27:4, pp. 541-66.

Maddison, Angus and Bart van Ark. 1988. "Comparisons of Real Output in Manufacturing." *Policy, Planning and Research Working Papers (WPS5)*. World Bank: Washington, D.C.

Maddison, Angus and Bart van Ark. 1994. "An International Comparison of Real Output, Purchasing Power and Labour Productivity in Manufacturing Industries: Brazil, Mexico and the USA in 1975." *Research Memorandum, No. 567 (GD-6)*. Groningen Growth and Development Centre: Groningen.

Marques, Rosane Argou. 2004. "Evolution of the civil aircraft manufacturing innovation system: A case study in Brasil," in *Innovation, Learning and Technological Dynamism of Developing Countries*. Sunil Mani and Henny Romijn eds. Tokyo; New York: United Nations University Press, pp. 77-106.

Montoro, Guilherme Castanho Franco, Marcio Nobre Migon, and Afonso Carlos Corrêa Fleury. 2009. *Cadeia produtiva aeronáutica brasileira: oportunidades e desafios*. Rio de Janeiro: BNDES.

Mulder, Nanno, Sylvie Montout, and Luis Peres Lopes. 2002. "Brazil and Mexico's Manufacturing Performance in International Perspective, 1970-98." *Research Memorandum GD-52*. Groningen Growth and Development Centre, University of Groningen: Groningen.

Stuivenwold, Edwin and Marcel Timmer. 2003. "Manufacturing Performance in Indonesia, South Korea and Taiwan before and after the Crisis. An international Perspective, 1980-2000." *Research Memorandum GD-63*. Groningen Growth and Development Centre: Groningen.

Szirmai, Adam, Ruoen Ren, and Manyin Bai. 2005. "Chinese Manufacturing Performance in Comparative Perspective, 1980-2002." *Discussion Paper No. 920*. Yale Economic Growth Center: New Haven, CT.

Timmer, Marcel P. 1996. "On the Reliability of Unit Value Ratios in International Comparisons." *Research Memorandum GD-31*. Groningen Growth and Development Centre.
Timmer, Marcel. 2000. *The dynamics of Asian manufacturing : a comparative perspective in the late twentieth century*. Cheltenham, UK ; Northampton, MA, USA: Edward Elgar.
Vertesy, Daniel, *Where the Wings Come From*, PhD Dissertation, forthcoming 2010

Aircraft Value News articles:
2004. "7 Percent Hike in Boeing List Prices Keeps Pace with Value Recovery." *Aircraft Value News*, Vol. 13: 1.
2006. "Boeing List Prices Exhibit Substantive Rise." *Aircraft Value News*, Vol. 15: 1.

Statistical Sources:
AIAB, Aerospace Industries Association of Brazil, *Industry Numbers*. (Unpublished data, courtesy of Mr. Walter Bartels)
Airlinerlist online database, Embraer tables, URL: www.airlinerlist.com (retrieved: Feb 2009)
American Aerospace Industries Association 2008 "Shipments: U.S. Civil Jet Transport Aircraft, 1996-2006" *AIA Aerospace Statistics Series 21*: *(Annually)* online statistics, URL: www.aia-aerospace.org (retrieved April 2008)
Boeing, 2008, Online aircraft specifications, URL www.boeing.com (retrieved June 2008)
Embraer, *2006 Embraer Annual Report*. URL: www.embraer.com, (retrieved June 2008)
_______, 2006, *Financial Statements for the Years Ended December 31, 2006 and 2005 and Independent Auditors' Report* URL: www.embraer.com, (retrieved June 2008)
EUKLEMS Growth and Productivity Accounts database, November 2009 release. URL: www.euklems.net
GGDC, Groningen Growth and Development Centre, 60-Industry Database, September 2006, URL: http://www.ggdc.net/, updated from O'Mahony and van Ark (2003).
IBGE, 2005, *Pesquisa Industrial 2005, Produto*, vol. 24, no.2. URL: http://www.ibge.gov.br/english/estatistica/economia/industria/pia/produtos/produto2005/default.shtm
IBGE, *Pesquisa de Inovação Tecnológica 2005*, Tabelas CNAE. http://www.ibge.gov.br/english/estatistica/economia/industria/pintec/2005/default.shtm (Retreived: 2008 October 31)
OECD STructrural ANalysis database online (OECD-STAN). URL: http://stats.oecd.org
U.S. Census Bureau, 2005, *Annual Survey of Manufacturing 2005*, online database, (retrieved November 2007), URL: http://www.census.gov/manufacturing/asm/index.html
U.S. Census Bureau, 2006, "Civil Aircraft and Aircraft Engine; and Aerospace Industry – 2005", *Current Industrial Reports*, online edition, (retrieved November 2007), URL: http://www.census.gov/manufacturing/cir/index.html
UNIDO, Industrial Statistics IndStat 2007, Rev.2 and Rev.3, CD-ROM edition.
The World Bank, *World Development Indicators Online*. Online database.

Annex I.

The ICOP methodology for output comparison

For such an exercise, data should ideally be available on produced quantity and producers' prices. Given that such information is rarely the at hand, unit values (*uv*) (or shadow prices) of productsare calculated, dividing ex-factory output value (*o*) by quantity produced (*q*) (A1). Unit value ratios (UVRs) are calculated for each matched product from the two countries (A2) that actually indicate relative producer prices. For a sample of broadly defined products with similar characteristics from the two countries aggregate (UVRs) are calculated in two ways: by using output weights of the base country, resulting in a Laspeyres-type (A3) and of the home country, resulting in a Paasche-type index (A4). The two are harmonized in a geometric average, the Fisher index. For the purposes of this study, aggregation to branch level or national level will not be required. However, certain adjustments are necessary to the product matching, given data limitations, as described in the following sections.

$$uv_i = \frac{o_i}{q_i} \qquad \text{(A1)}$$

$$UVR_i^{BU} = \frac{uv_i^B}{uv_i^U} \qquad \text{(A2)}$$

$$\mathrm{UVR}_j^{\mathrm{BU(U)}} = \sum_{i=1}^{I_j} w_{ij}^{\mathrm{U(U)}} \cdot \frac{uv_i^B}{uv_i^U} = \frac{\sum_{i=1}^{I_j} uv_i^B \cdot q_i^U}{\sum_{i=1}^{I_j} uv_i^U \cdot q_i^U} \qquad \text{(A3)}$$

$$\mathrm{UVR}_j^{\mathrm{BU(B)}} = \frac{\sum_{i=1}^{I_j} uv_i^B \cdot q_i^B}{\sum_{i=1}^{I_j} uv_i^U \cdot q_i^B} \qquad \text{(A4)}$$

Where uv_i = unit value of product *i* of the aerospace industry
o_i = ex-factory price of product *i* of the aerospace industry
q_i = produced quantity of product *i* of the aerospace industry
w = weight
UVR = unit value ratio
U = United States (base country)
B = Brazil

Annex II.

Definition of industrial classifications

USA, Aerospace industry

NAICS 3364 – Aerospace Product and Parts Manufacturing

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing complete aircraft, missiles, or space vehicles; (2) manufacturing aerospace engines, propulsion units, auxiliary equipment or parts; (3) developing and making prototypes of aerospace products; (4) aircraft conversion (i.e., major modifications to systems); and (5) complete aircraft or propulsion systems overhaul and rebuilding (i.e., periodic restoration of aircraft to original design specifications).

336411 – Aircraft Manufacturing

This U.S. industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing or assembling complete aircraft; (2) developing and making aircraft prototypes; (3) aircraft conversion (i.e., major modifications to systems); and (4) complete aircraft overhaul and rebuilding (i.e., periodic restoration of aircraft to original design specifications).)

33641131 – Aircraft Manufacturing, Civilian

civil aircrafts (fixed wing, powered); helicopters; other civil aircrafts (non-powered) and kits

(*Source:* U.S. Census Bureau)

Brazil, Aerospace Industry

CNAE (1.0) 353 – Construction, Assembly and Repair of Aircraft

Includes the construction and assembly of passenger, sports, military, etc. aircraft, the construction of helicopters, hang-gliders, gliders and other aircraft with or without motor; the construction of spacecraft, satellites, sensors and weather balloons for meteorological or other purposes. It also includes the manufacture of engines and aircraft parts and components, the manufacturing of flight simulators, as well as the repair and maintenance of aircraft, turbines and aerospace engines. (It does not include the manufacture of parts and accessories for electric aircraft, or equipment and instruments for aerial navigation.)

(*Source:* IBGE)

Annex III.1 Trends in Labour Productivity Levels in the Aerospace Industry, Brazil and USA, 1970-2007

Years	United States				Brazil					Brazil/USA		
	Value Added m USD, constant (2000=100)	**Employees**	**Labour Productivity** 1000 USD/EMP (2000=100)	**Labour Productivity** 3-year moving average	**Value Added** m BRL, constant (2000=100)	**Value Added** m USD, constant (2000=100)	**Employees**	**Labour Productivity** 1000 USD/EMP (2000=100)	**Labour Productivity** 3-year moving average	(USA=100)	3-year moving average (USA=100)	Transport equipment manufacturing (Mulder *et al*, 2002)[a] (USA=100)
1970	46,615.4	694,611	67.1	71.6	19.7	12.9	n/a					55
1971	42,748.1	561,090	76.2	71.3	15.6	10.2	n/a					55
1972	40,547.8	575,038	70.5	74.8	69.1	45.1	n/a					62
1973	46,749.4	600,660	77.8	75.6	77.6	50.6	3,086	16.4	15.4	21.1	19.8	64
1974	48,182.9	614,900	78.4	78.2	112.6	73.4	5,074	14.5	16.0	18.5	20.4	87
1975	45,644.8	582,552	78.4	78.0	133.6	87.1	5,120	17.0	16.5	21.7	21.2	72
1976	42,446.4	550,088	77.2	78.3	177.6	115.8	6,451	18.0	17.1	23.3	21.8	71
1977	43,912.3	552,920	79.4	78.9	155.4	101.4	6,266	16.2	17.3	20.4	21.9	67
1978	48,373.4	604,656	80.0	80.0	178.7	116.5	6,565	17.8	17.9	22.2	22.3	69
1979	55,545.4	689,282	80.6	79.8	230.2	150.2	7,614	19.7	18.2	24.5	22.8	76
1980	58,526.5	742,560	78.8	77.4	238.9	155.8	9,095	17.1	21.1	21.7	27.5	85
1981	53,520.3	734,000	72.9	75.1	334.8	218.3	8,266	26.4	20.2	36.2	27.0	83
1982	50,433.2	685,000	73.6	71.1	267.3	174.3	10,278	17.0	20.4	23.0	28.6	68
1983	46,148.5	690,000	66.9	70.1	285.7	186.3	10,499	17.7	15.6	26.5	22.4	60
1984	48,281.0	693,000	69.7	71.8	218.8	142.7	11,672	12.2	14.9	17.5	20.9	54
1985	58,918.1	746,000	79.0	75.1	265.6	173.2	11,758	14.7	16.2	18.7	21.4	56
1986	61,280.1	798,000	76.8	80.4	465.0	303.3	14,100	21.5	20.6	28.0	25.6	56
1987	69,276.8	810,000	85.5	80.8	593.8	387.3	15,100	25.6	24.0	30.0	29.7	51
1988	65,702.2	820,000	80.1	82.3	419.9	273.9	11,000	24.9	30.5	31.1	37.2	52
1989	66,863.1	823,000	81.2	82.3	862.9	562.8	13,700	41.1	36.7	50.6	44.4	57
1990	69,868.2	816,000	85.6	88.4	677.5	441.9	10,000	44.2	39.3	51.6	45.1	62
1991	73,309.2	746,000	98.3	90.1	501.2	326.9	10,000	32.7	39.1	33.3	43.9	73
1992	58,637.9	678,827	86.4	91.5	438.9	286.3	7,100	40.3	34.1	46.7	37.6	77
1993	53,218.0	593,128	89.7	84.8	310.7	202.7	6,900	29.4	29.4	32.7	34.3	81
1994	41,797.2	534,611	78.2	82.7	195.2	127.3	6,900	18.5	24.2	23.6	29.1	84
1995	40,160.4	501,220	80.1	82.3	289.3	188.7	7,600	24.8	26.6	31.0	31.9	89
1996	44,244.5	498,806	88.7	84.8	388.7	253.5	6,943	36.5	39.5	41.2	46.4	106
1997	45,036.4	526,628	85.5	89.8	699.0	455.9	7,965	57.2	51.1	66.9	56.9	111
1998	53,847.2	565,667	95.2	92.8	920.8	600.6	10,070	59.6	75.4	62.7	80.4	102
1999	52,004.7	531,780	97.8	97.3	2,022.0	1,318.8	12,071	109.3	97.2	111.7	99.5	*96*
2000	48,925.7	495,180	98.8	102.4	2,559.5	1,669.4	13,617	122.6	132.8	124.1	128.7	*110*
2001	53,967.6	487,377	110.7	108.7	3,875.5	2,527.8	15,180	166.5	155.2	150.4	142.0	*119*

2002	52,629.0	451,532	116.6	113.4	3,985.1	2,599.2	14,728	176.5	145.5	151.4	128.3	*107*
2003	47,949.3	425,217	112.8	120.8	2,813.7	1,835.2	19,604	93.6	120.9	83.0	101.3	*90*
2004	55,498.4	416,863	133.1	133.8	3,194.7	2,083.7	22,496	92.6	80.0	69.6	62.4	*95*
2005	67,853.5	436,578	155.4	154.7	1,942.9	1,267.2	23,522	53.9	64.6	34.7	43.7	*81*
2006	78,111.2	445,094	175.5	182.3	1,991.3	1,298.8	27,408	47.4	48.6	27.0	27.4	*78*
2007	99,143.5	459,270	215.9	195.7	2,096.6	1,367.5	30,742	44.5	45.9	20.6	23.8	*75*

Sources: OECD STAN, EU KLEMS, IBGE, US Census Bureau, UNIDO (see text), Mulder *et al*, 2002, Fig.4.p.19. *Note:* (a) 1999-2007 figures in italics updated series with recent IBGE data

Annex III.2 Key indicators of the Brazilian Aerospace Industry and Embraer, 1996-2009 (in constant 2000 USD)

	Aerospace Industry						Embraer				Aerospace Industry less Embraer	
Years	**GO** mln USD	**VA** mln USD	**VA/GO**	**SA** mln USD	**EMP**	**NE**	**SA** mln USD	**EMP**	**NI** mln USD	**NI/EMP** 1000 USD	**SA** mln USD	**EMP**
1996	671	356	0.53	687	6,943	76	402	3,849	-125.7	-32.67	285	3,094
1997	1,254	643	0.51	1,234	7,965	71	782	4,494	-31.4	-7.00	452	3,471
1998	2,147	843	0.39	2,043	10,070	79	1,404	6,737	150.3	22.31	640	3,333
1999	4,394	1,854	0.42	4,098	12,071	92	1,877	8,302	240.1	28.92	2,221	3,769
2000	4,975	2,347	0.47	5,145	13,617	95	2,757	10,334	321.0	31.06	2,388	3,283
2001	7,555	3,556	0.47	7,061	15,180	96	2,853	11,048	320.3	28.99	4,208	4,132
2002	6,639	3,656	0.55	6,750	14,728	111	2,421	12,227	214.0	17.50	4,329	2,501
2003	5,536	2,581	0.47	5,271	19,604	108	2,026	12,941	127.8	9.88	3,246	6,663
2004	6,709	2,931	0.44	6,487	22,496	106	3,063	14,658	347.1	23.68	3,424	7,838
2005	5,226	1,783	0.34	5,283	23,522	115	3,353	16,953	394.6	23.28	1,930	6,569
2006	4,725	1,826	0.39	4,943	27,408	136	3,225	19,265	334.5	17.36	1,718	8,143
2007	5,678	1,900	0.33	5,746	30,742	137	4,383	23,734	408.6	17.22	1,363	7,008
2008	..	..	..	..	..	..	5,181	23,509	318.1	13.53	..	..
2009	..	..	..	..	..	..	4,414	16,853	201.1	11.93	..	..
Growth 96-02	9.89	10.26	1.04	9.83	2.12	1.46	6.03	3.18			15.19	0.81
Growth 03-07	1.03	0.74	0.72	1.09	1.57	1.27	2.16	1.83	3.20	1.74	0.42	1.05

Sources: IBGE, Embraer Annual Reports;

Notes: GO = Gross Output; VA = Value Added; SA = Sales; EMP = Annual Average Number of Employees; NE = Number of Enterprises; NI = Net Income; .. = not available. Transport sector deflators from FGV and UVR as calculated in the present study, backdated to 2000 applied for IBGE industry data in BRL, and World Bank World Development Indicators GDP deflators applied on company report figures in USD.

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