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ARTICLE

# The machinery value chain in Brazil: mapping for upgrading*

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**ABSTRACT**

This paper aims at mapping machinery value chains in Brazil to check the validity of the smiling curve and the impacts of the COVID-19 crisis, investigating opportunities for upgrading. The empirical methodology is based on qualitative research among 50 machinery manufacturing companies in three steps: online survey, interviews, and poll. The main conclusion is that the executives in our sample are sceptical about the smiling curve in Brazil. The COVID-19 crisis seriously impacted most of the consulted machinery companies, and it has caused significant disruptions in their value chains. Companies that reduced their chain's dependence on suppliers, relying on local networks and verticalization, had more hedge against those ruptures. The executives have shown eight fields of opportunities to upgrade in value chains. The paper contributes to the international literature on Management through its innovative methodology and insights for companies from developing countries.

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## 1. Introduction

The fast-growing technologies that are changing the world's productive paradigms during the COVID-19 pandemic (advanced manufacturing, industry 4.0, internet of things (IoT), robotisation, artificial intelligence, digitalisation, etc.) are associated with machinery value chains. In order to avoid disruptions and to improve the resilience of supply and value chains, it is necessary to understand both structural and conjunctural issues faced by companies from different countries and regions, rethinking supply chains in a broad sense (Jabbour et al., 2020; Sarkis, Cohen, Dewick, & Schröder, 2020). For preparing the field to manage value chains, allowing management strategies and public policies to the unexpected events such as the current pandemic (Van Hoek, 2020), there is a need to know their configurations, i.e. their maps of value-added (Reis, Barroso de Souza, Araujo, & Blind, 2021). Due to limitations in available data and the idiosyncrasies of individual value chains, case studies are required (Kaplinski & Morris, 2001). Therefore, this paper contributes to the interdisciplinary literature, and to corporate management strategies and public policies, by mapping machinery value chains in Brazil.

The machinery value chains in Brazil involve approximately 8000 companies (ABIMAQ, 2020) participating in complicated productive networks for a wide range of products. Considering that it would be impossible to depict those networks on a map and that our research's final goal is to support normative action regarding upgrading, especially resilience strategies in the short and long term, the global value chain (GVC) framework (De Marchi, Di Maria, Golini, & Perri, 2020; Gereffi, 2014) and the smiling curve (Shih, 1996; OECD & WTO, 2013) were adopted as main references for our case study.

From these references we formulated the first question in our research: 1) does the smiling curve currently hold for the value chains of machinery companies in Brazil? Our research can then answer (2) what upgrading opportunities are available to those companies? Our main initial hypothesis is that the smiling curve cannot be taken for granted for all industries and/or local and regional chains, including the machinery chains of Brazilian

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and global companies. In other words, the types of insertion into the global value chains (GVC) vary, and so do added-value curves. Consequently, firms are differently exposed to chain disruptions (Yu, Jacobs, Chavez, & Yang, 2019), such as those arising from the COVID-19 pandemic and its related economic crisis (Islam, 2021). In this sense, (3) how did the pandemic impact the machinery value chains in Brazil? (4) What corporate reactions were initiated to mitigate the effects of the pandemic and to improve the resilience of value chains in a post-pandemic world? and (5) What public policies are needed to upgrade in the short and long term?

To investigate our main hypothesis and to answer those questions, we developed a unique empirical approach performed in 3 stages. ABIMAQ (Associacao Brasileira da Industria de Maquinas e Equipamentos) supported the 3 stages of the survey by providing feedback on the design of questionnaires and disseminating our invitation to participate to its member's companies. Besides the introduction and conclusion, our paper consists of 5 sections: Section the literature review; Section the methodology and sample description; Section Smiling curve? Not yet for the machinery value chains in Brazil the results of our survey and interviews, showing the machinery companies' perceptions of value-added per chain's activity and upgrading opportunities; Section Impacts of the COVID-19 crisis in the machinery value chain in Brazil, an exploratory analysis of the impacts and reactions to the COVID-19 crisis based on the express poll; Section Policy recommendations for the Brazilian upgrading in machinery value chains, some policy and strategy recommendations for the Brazilian machinery value chain at the firm and the country levels, for the short and long term, and during and after the pandemic.

## 2. Literature review

The GVC framework (De Marchi et al., 2020; Gereffi, 2014) seeks to be an 'interdisciplinary theory building in an age of globalization' (Sturgeon, 2008). In spite of various international production/supply chain/network approaches, the simplicity and coverage of the GVC concept mean it has been often referenced by multilateral institutions such as the World Bank, OECD, UNCTAD, WTO, European Commission, especially for policy recommendations; The GVC framework can be operationalised in the quantitative analysis mode, allowing results achieved by public policies to be measured (Sturgeon, 2008).

GVC frameworks commonly illustrate the added value per activity as a smiling curve, created for the computer industry's value chain (Shih, 1996). The smiling curve has three sets of activities and tasks – pre-production, production, and post-production (OECD & WTO, 2013). Productive costs are mostly of tangible manufacturing activities and assets while the others are of intangible operational activities and assets. Some key activities prior to the tangible production stage are research & development (R&D), design, and logistics/purchase of inputs for manufacturing. After production, the intangible activities of logistics, marketing, and sales add value to goods and services ready for customers.

The smiling curve is the main reference for the ideas of governance and upgrading, assuming that adding more value means more investments in intangible chain activities (Mudambi). This framework has been used to explain the distribution of value-added gains between developed and developing economies, assuming that TNC concentrates in advanced economies on the production stages that generate high value-added, while in developing economies they perform low-end and tangible production activities, the bottom portion of the smile curve (Asian Development Bank et al., 2021). These locations result from the governance of chains' activities, from less to more vertically integrated and global (Gereffi, Humphrey, & Sturgeon, 2005). Upgrading, then, is the socio-economic improvement of the activities and tasks performed by people in companies and in countries, shifting from low-value to relatively high-value activities (Barrientos, Gereffi, & Rossi, 2011; Gereffi, 2014). Upgrading possibilities are related to governance schemes that configure different insertions into GVC (Giuliani, Pietrobelli, & Rabellotti, 2005), orbiting around powerful multinational firms that lead most innovations and adopt different strategies for knowledge transfer to subsidiaries in developing countries.

Building competitive differentials that enable upgrading in the chains in the face of clearly unequal competition has been a great challenge for companies from developing countries, especially micro, small and medium-sized enterprises (World Bank, 2020). This was clear in the COVID-19 pandemic because the disruptions in the flows of capital, goods, and services have caused interruptions in the productive processes, products shortages, and price oscillations (United Nations Conference on Trade & Development, 2021). But the pandemic occurs while restructurings of GVCs were already underway, especially since the financial crisis in 2008/09, provoked by three

main drivers in the international production system: (a) 4.0 technology; (b) geopolitical disputes; (c) the imperative for sustainability (United Nations Conference on Trade & Development, 2020).

These trends are not merely market-driven transformations based on cost-benefit optimizations; they also present strategic and political determinants (United Nations Conference on Trade & Development, 2021). In this sense, since the mid-2000s, China has strengthened as the main centre of production and destination of added value in global chains, taking the lead even in computers and electronics replacing the United States and Korea. However, the primacy has not yet spread to all industries, such as automobiles, still led by Germany and the USA. In the services sector, high-income economies lead the way, such as the US, the UK, Germany, and France. But in machinery, China is the top world manufacturer with a 35% share of the manufacturing value added (MVA) in 2019, followed by USA, Germany, Japan, and Italy. Among the developing economies but China, India is the leader with 26% of the MVA, followed by Brazil (12%), according to the latest data available from United Nations Industrial Development Organization (2021).

Since competition among companies from larger economies is expected to grow as the "new normal" settles down (Organization for Economic Cooperation & Development, 2021), governments and business groups are looking not only to make their chains more resilient to systemic shocks but also to build more robustness and opportunities to improve the quality of their GVC insertion (Miroudot, 2020). These imply new paths to reindustrialization based on reshoring, industrial diversification, regionalisation, and replication investments (United Nations Conference on Trade & Development, 2020, 2021). Therefore, the state has acquired a more active role in the economic and political sphere, not only because of the need for countercyclical measures to circumvent the COVID-19 crisis (Islam, 2021) but as a long-term inducer of investments in the strategic technologies and industries of the first half of the twenty-second century, considering the sustainable 4.0 paradigm.

However, the industrial policy efforts of the world's major powers should lead to a greater concentration of power and wealth, pushing companies in peripheral and/or less relevant countries away from the core of GVC, where the profits of the world's productive and financial technological patterns are appropriated (Durand & Milberg, 2020). In this sense, for preparing positive and normative analysis, the initial step is to map the GVC, particularly the added value of tangible/intangible activities (Reis et al., 2021). This is a complex task because the value per activity or its components (costs/price, wages/profits) are pieces of information generally not publicised by the firms. because they consider the information strategic or, often, they cannot calculate value or profit from specific activities (Linden, Kraemer, & Dedrick, 2007). Therefore, case studies at the firm or at the country levels have been trying to detect value-added per activity based on financial data, leading to controversial results on the validity of the smiling curve (e.g. the conclusions of Li Sun, Chen, and Pleggenkuhle-Miles (2010), Szalavetz (2017), Rehnberg and Ponte (2018) are consonant to the smiling curve, while Shin, Kraemer, and Dedrick (2012), Luan and Tien (2015), Shen, Tang, and Chow (2018) and Meng, Ye, and Wei (2020) show inverted-U shaped curves for value-added per activity).

## 3. Methodology

### *3.1. Three steps process: questionnaire, interviews, express poll*

Coherently, considering that our research's final goal is to support normative action, especially regarding upgrading and management strategies for improving the insertion into productive chains, we adopted the GVC framework and the smiling curve as the main references for our case study. We wanted to understand how much the machinery companies in Brazil agree with the smiling curve, ranking the importance of their activities. The rationality supporting the questionnaire's structure was to investigate our hypothesis in value-added per activity based on structural and financial information, respecting the recommendations for qualitative research from Doz (2011).

To ensure reliable answers, the survey had to engage senior executives who had both a strategical and an operational view of the value chain; a difficult undertaking. The questionnaire had three parts. The first part asked for general information about companies and respondents. The second part was about the companies' value chains, investigating agreement with the smiling curve, cost structure, and verticalization. Our strategy was to assess the perceptions of the respondents first through spontaneous answers, by asking the respondents to sort the chain's activities from higher to lower value-added. Next, the perceptions were obtained by stimulating the respondents to analyse the smiling curve, providing the degree of their agreement. Finally, the third part of the questionnaire had an open question about opportunities in the value chain. The questionnaire was compiled in

**Table 1.** Sample of the online survey.

| Size | BNDES* firms' classification by revenue | # Employees on average | ABIMAQ members' distribution | Sample firms' distribution |
|---|---|---|---|---|
| Micro | ≤R$ 360 thousand | 19 | 8.6% | 20.0% |
| Small | R$ 360 thousand to R$ 4.8 million | 37 | 42.9% | 36.0% |
| Medium | R$ 4.8 to R$ 300 million | 255 | 45.4% | 34.0% |
| Large | >300 million | 2443 | 3.1% | 10.0% |

Source: ABIMAQ (2020).
*Brazilian National Economic and Development Bank.

line with the legal norms on scientific practice and data security, as verified by the Data Protection Office at the university. It was made available in 2019 and had 50 answers.

Then, the respondents received an invitation to participate in a personal online interview, structured following a script with seven questions. We conducted 38 interviews, which were key to improving understanding of the companies' GVC insertions, the perception of added-value per chain activity and outsourcing practices, and the opportunities for upgrading.

Finally, by the time our research analysis was finished, the coronavirus pandemic has started. From 7 to 20th April 2020, we asked the research respondents to answer an express poll about the coronavirus crisis' impacts on their company's value chain, measures taken and public policies needed to mitigate those impacts in the short-run (next 3 months), and in the medium run (2020–2024). The survey, interview, and poll responses were encoded and analysed in aggregate, maintaining the anonymity and confidentiality of individual information (see the Supplemental file for accessing the questions and answers of the three-step process of our case study).

### *3.2. Sample profile*

Our qualitative research in Brazil included answers from 50 companies, both domestic and foreign, 22 (56%) medium and large enterprises (MLE – with more than 100 employees, including transnational corporations), and 28 (44%) micro and small enterprises (MSE – with fewer than 100 employees). The sample had a larger share of micro and larger companies than in the profile of the sector (Table 1). But, in terms of groups, the sample was fairly representing the profile of the sector, which has 52% of MSE and 48% of MLE.

The survey's target audience was senior executives: 20% CEOs/vice-presidents/founders and 68% directors or general managers in finance, engineering, or planning. Among the 50 respondents, there were only 2 women, indicating strong gender inequality at the top of the Brazilian M&E companies' hierarchy. After answering the questionnaire, 80% of the executives (19 from MLE and 19 from MSE) were individually interviewed.

In our sample, 31 companies' headquarters were in Brazil, 10 in Germany, 3 in Italy, 3 in the USA, and 3 in other countries. Less than half (22) had no foreign subsidiaries. The vast majority of the companies exported in 2018 (80%), but 66% had exported less than 40% of their total production (Figure 1). The companies produce machinery and their parts from all Machinery and Equipment (M&E) groups of products,6 from both general and specific user groups of machinery, particularly M&E for the food, beverage, and tobacco industries; engines, pumps, compressors, and transmission equipment; M&E installation; repair and maintenance of M&E; M&E for the plastics industry; M&E for metal quarrying and construction; and tractors and M&E for agriculture and livestock (see Figure 2).

## 4. Smiling curve? Not yet for the machinery value chains in Brazil

### *4.1. Chains' perception and reality*

Following the methodology, first we asked the respondents to rank the chain activities according to their perceived value. The results were striking: no ranking was repeated by another respondent – suggesting that generalising a curve for M&E value chains is complicated. Moreover, 30% of the value-added curves derived from the rankings did present a shape similar to a smile, i.e. with the tangible activities at its bottom. For all companies in the sample, the respondents considered that R&D was the top activity in terms of value-added, followed by engineering and design, manufacturing, quality in manufacturing, and after-sales services–judging by the frequency of responses in the top two positions (Figure 3).

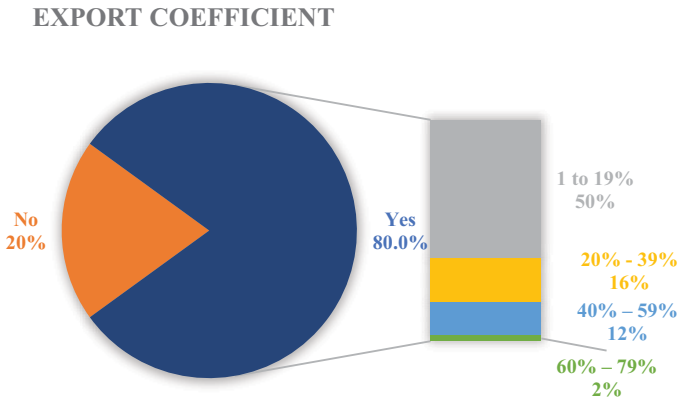



**Figure 1.** Export coefficient from the companies of the sample, 2018 (in % of total sales).

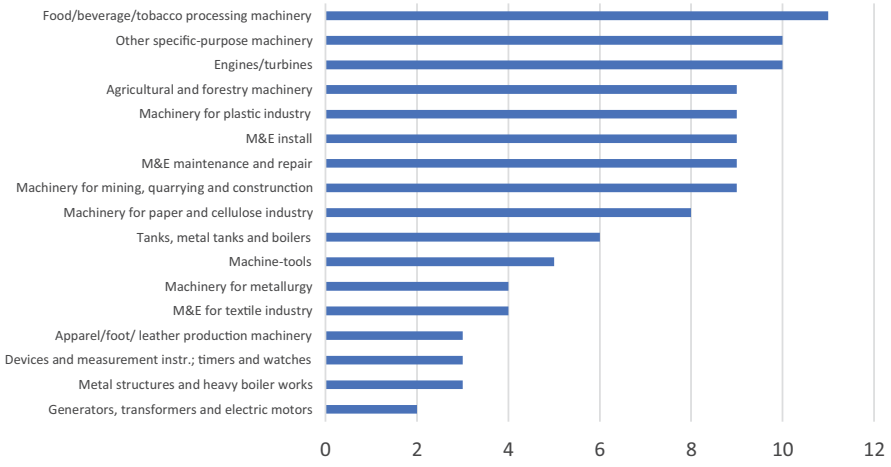



**Figure 2.** M&E manufactured by the companies of the sample, 2018 (number of companies).

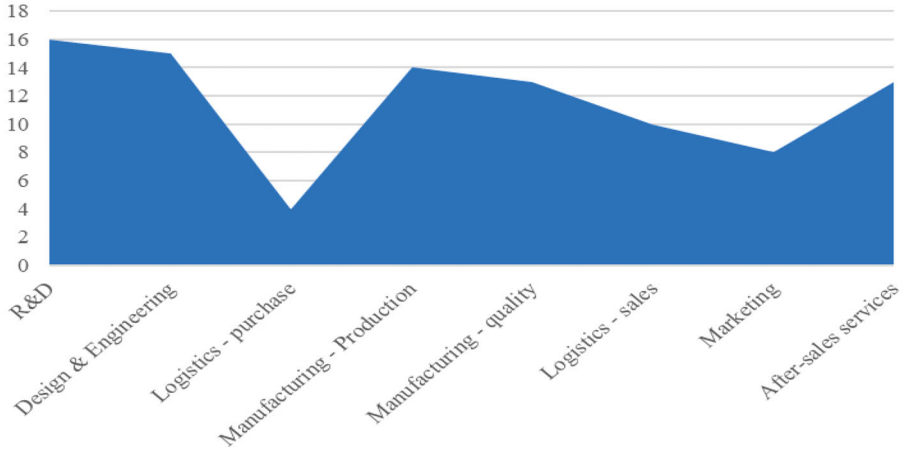



**Figure 3.** Activities' frequency in the top two positions of the perceived added value ranking, 2018 (number of answers from a total sample).

Coherently, when the respondents were later asked whether they agree that this curve represents the machinery value chains in Brazil today, only 40.8% said yes, regardless of the company's size. However, 75% believed that the smiling curve will be consolidated within 10 years (Table 2).

**Table 2.** Agreement in relation to the fitness of the smiling curve to describe the value per activity in the M&E industries today and within ten years, by company sizes' groups (% of answers/total sample).

| | Total | | Micro/Small enterprises | | Medium/Large enterprises | |
|---|---|---|---|---|---|---|
| | Today | Within 10 years | Today | Within 10 years | Today | Within 10 years |
| Fully disagree | 0% | 0% | 0% | 0% | 0% | 0% |
| Partially disagree | 29% | 8% | 26% | 4% | 32% | 14% |
| Not disagree, neither agree | 31% | 16% | 33% | 15% | 27% | 18% |
| Partially agree | 31% | 35% | 33% | 44% | 27% | 23% |
| Fully agree | 10% | 41% | 7% | 37% | 14% | 45% |

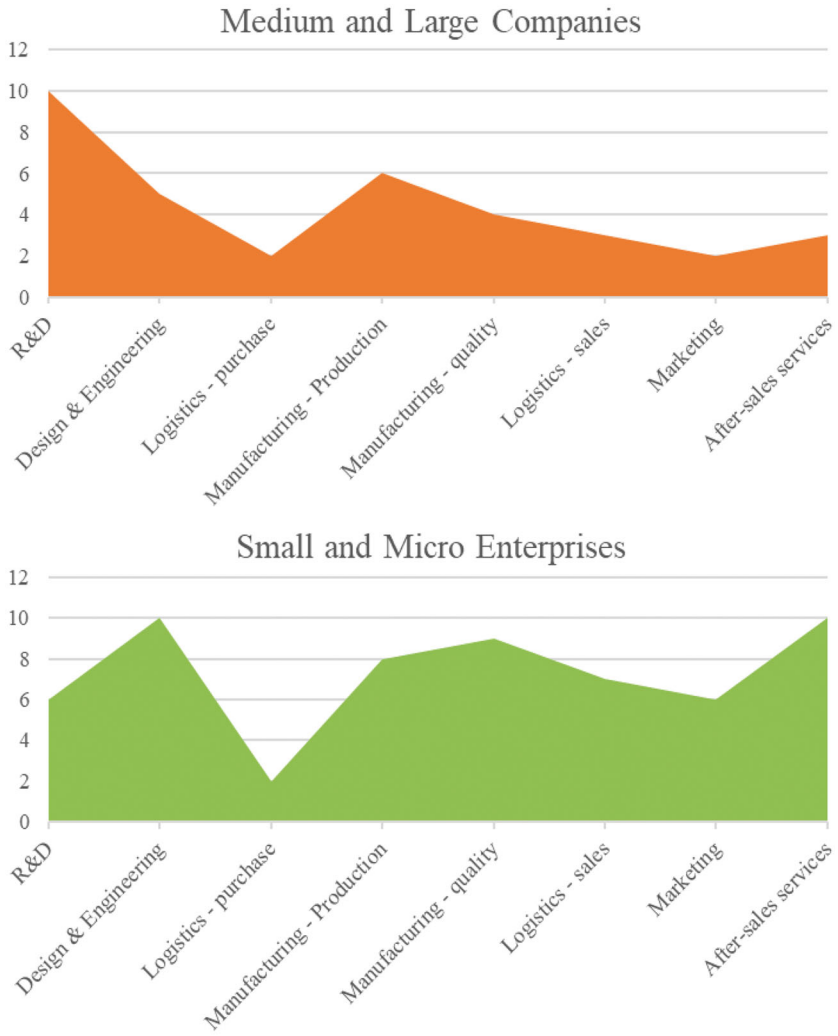
"To verify whether the perceptions of the executives were coherent to their agreement with the smiling curve, we performed a Chi-Squared test, which has been widely used to examine categorical data (Sharpe, 2015). Our $2 \times 2$ contingency table contrasted answers to the question regarding the smiling curve's perception (observed data) and the question regarding the agreement levels with that (expected data). In the former case, we considered that the smiling curve holds in the answers that attribute the lowest value-added to tangible activities ("production" and "quality"). And in the latter case, we considered that the smile curve holds in the answers "agree" and "fully agree." Our calculated chi-squared was 0.758, which is less than 3.841 for one degree of freedom, at a 0.05 confidence level. Thus, the null hypothesis of independence between the variables cannot be rejected, which means that the observed data lies close to the expected data."

However, the perceived value-added per activity varies significantly when regarding the responses from the MSE and MLE groups. As Figure 4 shows, the two most voted activities in terms of value-added for MSE are engineering and design and after-sales services, followed by manufacturing quality and production. But for MLE, R&D is the top activity in terms of added value, followed by production and engineering and design. Nevertheless, for both groups, the responses show that, in contrast to what the smiling curve suggests, Brazilian machinery executives do not consider a true that manufacturing/production is the activity that adds less value to the chain.

We can understand why the smile curve currently is not a reality according to the majority of the respondents in our sample considering, firstly, the basic operations of the firms in the Brazilian market, both of MSE and MLE. In the former case, they are still concentrated in the manufacturing itself. And in the latter case, the domestic operations of foreign larger firms focus on manufacturing, too, performing basic intangible activities in Brazil while leaving the key ones at the main headquarters of their GVC. As explained by the respondents, execution has to be excellent in the M&E industry because quality is paramount. This excellence is also a reason for companies in the machinery chains to highly value quality and after-sales service activities (installation and maintenance). In this sense, the respondents affirmed that "on-demand" products allow for more customised and higher value-added solutions, escaping the customer price/term dilemma of more generic "off-the-shelf" products.

Therefore, the differentiation to the customer is measured through the performance of the machine in operation, and its Total Cost of Ownership (TCO), including price negotiation and installation plans. In the case of standard tools or machines, the ability to add technology is very similar. Therefore, the way to stand out is through design quality, durability, execution quality, and, increasingly, after-sales. The sales teams need to be technically qualified to succeed in selling these differentials, but the after-sale services are even more important in this sector because the products must have frequent customer services. So, companies sell a how the package of solutions, through qualified presence at the customer's factory, proposing constant improvements in the operation process, training how to use the equipment and/or machinery, maintaining, and repairing. Issues of agility, flexibility, and delivery times are fundamental. In summary, delivering customised solutions in a fast, dynamic, and price-competitive way is the main way to be competitive. While delivering a customer-success-oriented after-sales service is the differential for perpetuating the relationship with the customer.

R&D and engineering/design governance decisions also depend on company size, the level of project sophistication, and whether or not a company is multinational. Some multinational companies in Brazil only adapt initiatives from their headquarters; others bet on innovations in their niche markets' forefront. There are those who prefer to hire specialised services and some that participate in new innovation schemes, such as open innovation, start-ups, or technology incubators. The machinery industry has many firms that are domestically developing technology (65% of the companies interviewed). In contrast, almost 46% of our sample, mostly MSE, rely on foreign technology and 38% make partnerships with internal and foreign suppliers.




**Figures 4.** Activities' frequency in the top two positions of the perceived added value ranking, 2018, by company size group (number of answers).

### *4.2. Opportunities for upgrading*

The questionnaire and interviews allowed excellent opportunities to be identified in the machinery GVC. They can be grouped in 8 fields as illustrated by the Sun Diagram in Figure 5, according to their frequency in the interviews' answers, explained in the subsections ahead.

In summary, the analysis of the interviews demonstrates that the main opportunities to improve the insertion of Brazilian companies into GVC are related to features from both the demand and the supply sides. For the total sample, the most quoted opportunities were Custo Brasil, trade and industrial policies, suppliers and inputs, demand, and macroeconomic regime. But looking at the groups of MSE and MLE, we find some remarkable contrasts. Firstly, for MSE, standards were mentioned by more than half of the executives as a key opportunity to improve their value chains, more than suppliers and inputs. Secondly, the fields of promotion and communication strategies and management and labour skills are stronger concerns for MSE than for MLE. Lastly, industry 4.0 is not yet on the MSE radar, as it was the least mentioned opportunity field. In contrast, for MLE, this field was actually the most quoted. These differences in the valuation of technology are striking and must be considered in policymaking, as emphasised in the conclusion of this paper.

#### *4.2.1 Technology/industry 4.0*

Companies from different segments of insertion into the machinery GVC have different perspectives about industry 4.0. While 62% of them perceive the new technological paradigm as a reality today and a medium-term necessity, many, especially small local companies or buyers, have not yet embraced these technologies. Around

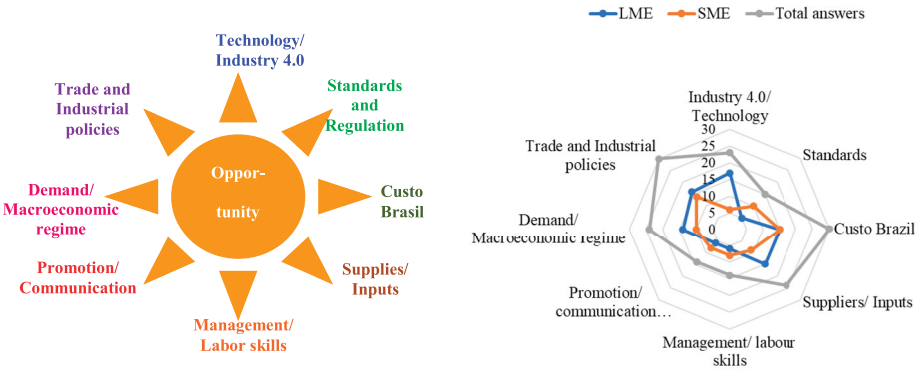



**Figure 5.** The Sun Diagram: Raised fields of opportunities in the machinery value chains, according to the interviews, number of answers, total companies, micro and small enterprises and medium and large enterprises.

20% of the interview respondents stated that opportunities are needed to solve basic modernisation issues that would immediately boost productivity ('our needs are still too basic', they claim). But the majority – especially active, follower and innovative companies – have already adopted some of these technologies, although they are still considered too expensive for MSE. Larger firms think that big data analytics and administrative software technologies enable the biggest initial gains, and many of them, notably multinationals, are already applying and producing 4.0 technology in their plants.

For some chains, artificial intelligence, automation, IoT and other digital and sustainable technologies are likely to change a company's profitability profile in favour of after-sales services' digitalisation in the medium term. According to some respondents, the transition to industry 4.0 cannot just happen at M&E companies; it requires suppliers and customers to keep up with the modernisation. They say that workers have to face the challenge to be prepared for this transition in order to avoid layoffs.

### *4.2.2. Standards and regulation*

For 40% of the participants, standards are opportunities for playing in GVC. For 30%, standards from other countries benefit their products as a guarantee seal for foreign customers. Attending to standards generally has a high cost, especially for small-scale producers. Often, certifications are an indispensable condition that facilitates management, adds value, and result in a greater profit margin. However, 14% of the respondents see standards as market barriers.

Therefore, trade agreements must be aware of non-tariff barriers, such as standards, that do not undermine the competitiveness of companies from all countries involved, especially MSE. In addition, according to the respondents, Brazilian domestic regulations are confusing and unstable, with problematic functioning. Improvements in design, coordination, and monitoring would be needed.

### *4.2.3. Custo Brasil*

For most interview respondents (81%), Custo Brasil (the cost differential in producing the same product in Brazil or abroad, as calculated by ABIMAQ, 2018) is a significant deterrent to the performance of M&E companies in GVC. Respondents claim they have learned to live with the high costs of doing business, but Custo Brasil is an impediment to innovations, especially for new entrants and young, growing firms (Dutz, 2018). Custo Brasil refers to the inadequate state of the country's physical infrastructure, regulatory obstacles, high tax rates, and complex tax system, high-interest rates and weak insolvency regime, and problematic processes when operating a business.

### *4.2.4. Supplies/inputs*

Executives (65%) indicated opportunities related to the structures of supply/inputs markets, the quality of these services, the tax system, dependence on imports, energy supply, etc. In Brazil, many raw materials or components' markets are oligopolies, such as steel or electronics. If they are focussed on other, larger, chains such as the automotive industry, they often do not offer solutions for the small-scale production of micro, small and medium M&E companies. The industry could work with these suppliers to develop customised solutions, enabling

more competitive costs for raw materials and components – which heavily burden local, buying, and active companies.

The choice of importing raw materials and parts is not necessarily a technological constraint but is always a financial one. On the one hand, imports depend on the exchange rate, tariffs, or other transaction costs generally related to international trade. On the other hand, the domestic conditions also play a role – the more difficult the productive investment and the chain's activities upgrading, the simpler is firms' specialisation in activities such as assembly, an adaptation of marketing initiatives, or tropicalisation of engineering projects. This regressive process is continuing in Brazil so that the country is losing its position as a South American export headquarters for multinational groups.

According to the respondents, the high verticalization degree of domestic companies is largely explained by the cascading tax system. On top of the call for tax reform, the M&E chain's suppliers must improve industrial services, especially those related to manufacturing, in order to incentive outsourcing. Starting with the basics, such as reducing losses (for instance in fairing or forging), ensuring punctuality and quality, with agile and secure contracts – notably for a power supply based on clean energy.

#### *4.2.5. Management/labor skills*

The key to increasing efficiency and profitability despite the 'Custo Brasil' is not restricted to capital investment; for 38% of the respondents, it includes improving administrative and productive processes and skills. The low-skilled labour force is a major concern for 24% of the executives. Solving this problem requires public policies strengthening the National System of Innovation and private initiatives for training and developing employee skills. The executives also think that, in a broad sense, all the agents throughout the chain, including customers, need to build an innovative mindset. As they emphasised, differentiated products, notably 'on-demand' goods and services, generate more value to the companies' chains by reducing the need to compete on price and payment terms in 'off-the-shelf' goods markets. Given the difficulties of innovating, such as high cost and technical capacity, innovative and active companies are finding modern solutions related to the sharing economy, open innovation, and partnerships with universities and technology centres.

In addition, to become more efficient, industry chains can promote new management solutions. Many companies are innovating in intangible services, and outsourcing activities by contracting experts for customised projects. MSE is betting on new customer relationship strategies such as machine leasing, online monitoring, and preventive and predictive industry 4.0 analytics. Agile project management responses were crucial to dealing with the problems related to the pandemic, especially the disruptions in value chains.

#### *4.2.6. Promotion/communication*

Some chain opportunities for 38% of the companies are related to asymmetric information costs, which impact transactions between the various agents and, consequently, sales and business promotion. Broadening markets and engagement into GVC of Brazilian companies could be done by improving the local, buyer, and active firms' abilities to complete procurement and merchandising in other languages and by modernising information technology facilities (website, applications, IoT, sensors) available in foreign languages (English and Spanish in particular).

Furthermore, digital portals or platforms where multiple value chain agents—suppliers, customers, research institutions, or export agencies – could easily meet would reduce transaction costs and information asymmetries. Enlarging the number of institutions that form the bridge between chain agents is also of great importance. Such solutions may be provided, for example, by the government or industry associations.

#### *4.2.7. Demand*

For 81% of the companies in our sample, upgrading in M&E GVC requires favourable demand and macroeconomic conditions. The macroeconomic regime has a significant influence on Custo Brasil, mainly regarding the exchange rate and the basic interest rates of the economy, impacting short- and long-term investment costs. As in the case of lowering import tariffs, currency devaluations are disadvantageous for the buyer or follower companies whose business models rely on imports, while benefiting exporting companies supported by domestic value chains. Credit conditions also have a strong impact on the M&E industry, not only in terms of interest rate levels but also on their conditionalities and guarantees. BNDES (Brazilian National Development Bank) and its

investment funds for capital goods have historically supported demand for M&E, as well as procurement policies of public companies such as Petrobras, but its scope is still mainly benefitting big firms. Overall, the exchange rate and prices and the economic growth stability are desirable for reducing uncertainty and, thus, enabling long-term planning.

Moreover, the demand must change also qualitatively. Respondents have said that 'the M&E customer already values quality, but could require solutions that encourage greater value addition'. So, it is a challenge to stimulate consumers to acquire a mindset that values higher-quality technological solutions that increase productivity and boost the economy in general while respecting an ecofriendly and socially-inclusive spirit.

#### *4.2.8. Trade and industrial policies*

According to 81% of the executives, there are opportunities to modernise the industrial policies in Brazil, one that needs planning with the participation of the productive sector and with a technical-scientific basis. They need to generate supply and demand incentives and be harmonised with long-term development. Policymakers must pay attention to the different types of insertion of M&E companies into GVC, which lead to different patterns of dependence on imports, export capacity, internationalisation strategies, technological generation, etc.

Regarding import tariffs, on the one hand, they jeopardise buyer or follower companies whose products consist of import adaptations, such as assembly. On the other hand, domestic products from local, active and innovative companies may become more vulnerable to international competition, notably from China, if tariffs are reduced. Thus, tariff reviews should be smart, selective, and gradual, consistent with other products of their supply chains such as electronics and steel.

Domestic export capacity of companies of all sizes has deteriorated not only because of the regional economic crisis but also because of the fierce competition that displaced Brazilian markets due to price, delivery, customer relationship, and/or product quality advantages. As a matter of fact, the regional chain in South America is currently significant for domestic exporting companies, so much so that this market should not be overlooked in trade agreements with Europe and North America. By investing in training, Brazilian subsidiaries of multinational groups that are able to maintain or enhance their strategic relevance in global chains have created administrative solutions and been able to meet headquarters' quality standards despite the Custo Brasil. Finally, public procurement policies continue to be relevant incentives for upgrading domestic M&E value chains.

## 5. Impacts of the COVID-19 crisis in the machinery value chain in Brazil

The generous participation of 32 companies (18 MSE and 14 MLE) in the express poll produced information on the impacts of COVID-19 on the machinery value chain in Brazil. The generalisation of the results is limited, due to the urgent and synthetic nature of the questionnaire and the small sample. However, the poll provides a summary of the vision of the executives of this industry consulted in the second month of the pandemic in Brazil.

Most, 53%, of the companies, were severely or very severely affected by the crisis so some executives reported the immediate possibility of bankruptcy. The main negative impact of the COVID-19 crisis was the drop in demand from domestic and foreign markets, bringing with it a retraction in production mainly of machinery but also of spare parts. The impossibility for the sales team to physically find new or visit existing customers and the cancellation of trade fairs contributed to hindering the prospecting of new business. The executives also reported ruptures in the national and international value chains, such as contract cancellations, transportation difficulties, and closed factories in Brazil and abroad, with increased prices of inputs and raw materials. For companies that counted on imports in their chains, the significant devaluation of the Brazilian currency, the Real, made productive inputs more expensive, eventually reducing margins. Logistics problems hindered or made it impossible to deliver goods and services from suppliers and to customers, restricting operations and rising costs, such as increased freight and input prices. Adding all these factors to default or late payments has meant that the crisis has seriously impacted the companies' working capital.

At the same time, during partial or full confinements, labour productivity has decreased due to the difficulty, restriction, or impediment of employees to go to the office and/or factory (which in some cases was closed) and to their lower efficiency at home offices. The poor climate damaged employee health, as people had to deal with disturbing concerns regarding the spread of the virus, the maintenance of their own jobs, and the general effects of the health, economic, political, and social crisis. Nonetheless, in some companies, the crisis was less marked,

due to sustaining demand, shielding from disruptions in the value chain, agile reconfiguration of operations, or actions in specific industrial niches. Orders increased for some 'on-demand' products or products associated with health and food chains (for example, filters, temperature conditioners, or respirators). However, the new demands far from offset the losses.

According to 71% of valid responses, companies had changes in the value relationship between tangible and intangible chain activities, but no definitive trend has been identified yet. For a small number of the companies, intangible activities began to add more value than tangible activities during the pandemic, focussing on developing new products, being more active in sales and after-sales to maintain or create businesses, improving human resources for employee welfare management, and information and communication technology to ensure the virtual functioning of the company, and in the financial area realigning capital inflows and outflows, also highlighting the greater performance of accounts payable. Certain companies have been able to soften the problems derived from ruptures in the value chains due to their high degree of verticalization, or their strategic portfolio and sustainable relationship with suppliers, with less foreign dependence.

Nevertheless, an immediate effect has prevailed: most companies had to prioritise tangible activities; that is, the focus was on production, with the aim of reducing costs considered non-essential during the pandemic, such as direct and indirect expenses with R&D, engineering, sales, and marketing activities. In the evaluation of 25% of the total sample, some of the pandemic's effects on reorganising management, operation and production would be permanent, such as the valuation of sanitary procedures, advances in information technology and telecommunications, the opening of markets, the reconfiguration of supply chains, and the relationships with customers.

The last thing worthy of mention is that both groups of companies in the sample spontaneously reported similar impacts of the crisis derived from the pandemic. However, some impacts were stronger for MSE: interrupted logistics, troubles with working capital, sales payment defaults (so that the importance of accounts payable has increased), the possibility of bankruptcy, supplies' price increases, and short-run oriented management of the value chains in benefit of tangible activities to sustain production and 'cash flow'. Differently, MLE reports more problems with disruptions to the international value chain and a decrease in production, as well as an increase in orders for essential industries tackling COVID-19 pandemics, probably due to their greater flexibility in converting factories. MLE business models had more room for initiatives to improve information and communication technology activities and the relationship with customers and suppliers, such as repair and maintenance and after-sales services.

## 6. Policy recommendations for the Brazilian upgrading in machinery value chains

Based on the general learnings of our research, especially in the field of opportunities for upgrading in GVC, it is possible to make some normative recommendations for public policies and entrepreneurial strategies to improve the insertion of companies into M&E GVC, in the short and long run. At the top of the list is that companies, governments, universities, multilateral institutions, and non-profit organisations, as well as other social representatives, must develop and disseminate methods of measuring value-added at the chain activity level. Then, by improving the value chain mapping, especially the origin of value-added in tasks and activities from firms and countries, it would be possible to implement more assertive and beneficial strategies – which should always consider the different types of insertion into GVC.

Regarding long-term policies, M&E companies highlight the following structural challenges to be tackled by public policies on the supply side, in addition to reducing the Custo Brasil (generally the only point emphasised by the Brazilian media debate): decentralising the financial system, improving support to MSE, financing the modernisation of national machinery, reducing bureaucracy, strengthening the national innovation system for improving workforce technical qualification. The most specific policy urged by the sector is the strengthening of FINAME (*Financiamento de Maquinas e Equipamentos*), the funding from the Brazilian National Bank of Development (BNDES) for the production and acquisition of machines and equipment. FINAME is key to sustaining demand and to incentive domestic producers, besides the mayor goal of modernising and improving competitivity of other-sectors' production. Respondents consider that it must become less bureaucratic and more accessible to micro, small and medium-sized companies. On the demand side, the policy list includes exonerating productive investments (especially taxes on machines), promoting exports (liberating export credits), establishing sustainable growth dynamics, harmonising tax and fiscal policies with monetary policies.

In turn, the strategies for machinery companies to upgrade in GVC are investing in performing domestic activities with higher added value, which also means acquiring more innovative technology – such as 4.0 – and governance models for their chains, and modernising management and operations processes. Because the executives believe that the smiling curve will hold within 10 years, M&E companies could invest in offering better-differentiated solutions for customers, from the GVC perspective – which means replacing the specialisation 'on shelf' by 'on demand' products or/and, at least, investing in intangible activities that are crucial for the sector, such as engineering or after-sales services for tailoring solutions together with the customers. To boost employees' performance, productivity, well-being, and permanence in the company, special training investments are required, including specific actions to improve a company's view of the value chain (often absent today). The machinery association ABIMAQ could work together with machinery suppliers' industrial associations – such as steel or electronics – to design solutions for small and medium scale M&E productions. It could also create a digital value chain platform, a website to promote the meeting of different domestic and foreign value chains' stakeholders. And, finally, ABIMAQ could improve machinery companies, especially MSE, with their international sales' digital promotion strategy, including the website design in English and Spanish, foreign markets prospection, foreign investors' orientation, etc.

Entrepreneurial strategies for the long run conflict with the action taken when facing the negative impacts of the COVID-19 crisis, as shown in Section Smiling curve? Not yet for the machinery value chains in Brazil. In general, long-term actions were marginalised by several companies, with the freezing or cancellation of productive investments. Regarding the disruptions in the value chain, the companies had to expand their ranges of suppliers, replacing those that did not deliver commitments, or outsource internal activities. They also accepted longer delivery and payment times for supplies and, consequently, delayed delivery and payment conditions of their products to customers. For working capital, they had to quickly undertake short- and medium-term financial planning, taking into account the government's economic support package – which mainly consisted of granting credit, allowing late tax payments, and social security commitments. These and other actions were taken by the Brazilian government during the pandemic were tracked by ECLAC (2020).

The vast majority of the companies in our sample started their reactions with the basics of health safety at work – respecting national, state and municipal rules – such as home office, shift schedules in factories/cafeterias/places of agglomeration, constant disinfection, use of individual protective equipment such as gloves and masks, temperature checks at the beginning of the working day and establishing anti-crisis committees. Some executives were concerned with spreading solidarity within the organisation and society, though the collaboration efforts vary depending on hierarchy levels, governance structures, and social responsibility. The companies were trying to handle the crisis intelligently based on the understanding among employees, customers and suppliers and other agents of the value chain and society in general. Many avoided layoffs, instead of promoting early vacations, reduced working hours, and wage renegotiations when labour restrictions were needed. Additionally, sectorial action had gained greater urgency and relevance so companies asked ABIMAQ and other industrial associations to pressure the public sector to take countercyclical initiatives. Nevertheless, some of the consulted companies stated that they had already fired staff. In reality, there were around 11,000 layoffs in the Brazilian M&E chains in April 2020 (ABIMAQ, 2020).

The short-term public policies (May-July 2020) demanded by the companies to mitigate the COVID-19 crisis demand and supply impacts mentioned in Section Smiling curve? Not yet for the machinery value chains in Brazil involve credit, tax burden, infrastructure, governance of the chain, cost management, and labour issues. The companies' specific priorities were, first, the release from private banks of the government's emergency credit for MSE followed by tax exemption or extension of tax payment periods. Despite a couple of executives advocating policies to sustain employment, many others called for new flexibilization in labour relationships and other neoliberal reforms in the public administration and tax systems.

M&E businessmen were also worried about how the Brazilian government and public institutions were managing the pandemic crisis. Improvements were demanded in planning, execution and monitoring, reducing friction among the Three Powers (Legislative, Executive, and Judiciary), reducing uncertainty, and calming down the population by effectively ensuring sanitary conditions to fight COVID-19. Executives were particularly unsure about the process of confinement entry and exit and the 'new normal' scenario. They were, in general, asking the government to support the economy by sustaining demand through public spending, which would encourage consumption and investment.

**Table 3.** Recommendations for public policies and entrepreneurial strategies to improve the insertion of Brazilian companies in M&E GVC.

| |
|---|
| ***Public policies*** |
| ✓ Industrial and trade policies considering types of insertion into GVC |
| ✓ Adopt pro-demand macroeconomic regime |
| ✓ Reduce Custo Brasil |
| ✓ Strengthen National Innovation System, |
| ✓ Improve institutions to support business competitiveness |
| ✓ Simplify bureaucracy; improve norms design and monitoring |
| ✓ Watch over the regional value chain (South America) |
| ✓ Integrate these actions into the national sustainable and social-inclusive development plan |
| ***Entrepreneurial strategies*** |
| ✓ Invest in activities to upgrade value chains |
| ✓ Pursue innovative governance for their chains |
| ✓ Offer differentiation solutions for customers, from a GVC perspective |
| ✓ Plan to join industry 4.0 and open horizons of technology generation |
| ✓ Suppliers: Design solutions for small and medium scale M&E productions. |
| ✓ Encourage M&E associations to create a digital value chain platform |
| ✓ Improve digital international sales promotion strategy |
| ✓ Invest in employees |

For the medium run (2020–2024), some poll's answers show a new vigour of sovereignty and developmentalism ideals. Aware of the global geopolitical disputes deepening (mainly between the US and China) and implications on GVC (such as more protectionism and deglobalization), some executives defend the national technological development, strengthening of local productive networks, promoted by an 'Entrepreneurial State' (Mazzucatto, 2014). But the majority is not worried about public action for harmonising tax and fiscal policies with monetary policies for maintaining and creating jobs. Let alone with a macroeconomic regime consistent with a national plan for sustainable and socially inclusive development (Epstein & Yeldan, 2008), democratically and transparently elaborated – a long-overdue process in Brazil. Instead, our recommendations for public policies in Table 3 are in favour of a pro-demand macroeconomic regime consistent with an inclusive development path.

## 7. Conclusions

The answer to our first research question – does the smiling curve currently hold for machinery value chains of companies in Brazil? – is no, as the executives in our sample are sceptical about the smiling curve, confirming our initial hypothesis. They believe that intangible activities will add more value than tangible ones within 10 years from now, but most think this is not the reality yet. R&D is the top activity in terms of value-added according to the survey's respondents, followed by engineering and design, manufacturing, quality in manufacturing, and after-sales services. In opposition to the implications of the smiling curve, manufacturing is not the activity that adds the least value in the chain, neither for micro/small nor for medium/large enterprise executives. How companies value each chain activity is not uniform and varies due to factors impacting the firm's integration into GVC such as size, product portfolio, capabilities, governance, etc. Therefore, mapping value chains requires segmenting firms by types of insertion into GVC. Considering firms different sizes and complexity, we propose classifying them according to two technology strategies, either as local buyers/global followers generally specialised in low value-added activities of the GVC or as active and global innovators specialised in high value-added activities.

For our second research question – what upgrading opportunities are available to machinery value chains of companies in Brazil –, the survey and the interview results suggested 8 different fields of opportunities: technology/industry 4.0, governance/labour skills, standards/norms, demand/macroeconomic regime, promotion/communication, suppliers/inputs, industrial/trade policies, and 'Custo Brasil'. Besides, companies, governments, universities, multilateral institutions, non-profit organisations, and other social representatives must develop and disseminate methods of measuring value-added at the chain activity level. Then, value chain mapping should be improved, especially the origin of value-added in tasks and activities in firms and countries, so that more assertive and beneficial strategies can be implemented, ones that consider the different types of insertion into GVC.

This concern is also important to tackle the problems related to the COVID-19 crisis in machinery value chains. In relation to research questions 3, 4, and 5, the express poll showed that the COVID-19 crisis seriously impacted most of the consulted machinery companies, and it has caused significant disruptions in their national and international value chains. Companies that reduced their chain's dependence on suppliers, relying on local networks

and verticalization, had more hedge against those ruptures. The crisis caused a temporary change in the relative importance of chain activities, privileging the maintenance of manufacturing, especially in small and micro companies – but management recognised the importance of the intangible in the long term. The ability to reorganise management strategies, either with anti-crisis committees or not, was also crucial to align expectations with stakeholders and prevent business from drifting apart.

The machinery industry in Brazil is calling for ambiguous public policies to overcome structural supply- and demand-side challenges in the post-pandemic world. The supply-sided policies are related to reducing 'Custo Brasil', decentralising the financial system, better support to small and medium enterprises, financing exports, relieving productive investment, funding the modernisation of national machinery, and reducing bureaucracy. We note, thus, a new vigour of developmental State ideals on industrial (Wade, 2012) policies in the productive sphere in the long run, but not necessarily in the distributive sphere. The demand-sided policies are related to establishing sustainable growth dynamics in the long run, but in the short run, the executives want to alleviate costs, asking for neoliberal labour, fiscal, and tax policies. Therefore, the public policies desired by the Brazilian machinery sector's businessmen show an ideological incoherence, which comes from the diversity of integration types into CGV of the domestic machinery companies, with varying degrees of dependence on external capital and technology.

In its turn, there are several opportunities for upgrading that depend on the companies' decisions. As discussed, the strategies for machinery companies to upgrade in GVC are investing in performing domestic activities with higher added-value, innovative technology new governance models for their chains, modernising management and operations processes, and improving labour skills. Because differentiated solutions for customers are paramount in this sector, a key strategy is to invest in intangible activities such as engineering or after-sales services. We also emphasised that there are issues in the supply chain causing high costs to small and medium scale M&E productions, especially related to iron and energy prices. In this sense, a digital value chain platform would help to alleviate market asymmetries, reducing information and transaction costs. Brazilian M&E companies need to improve their internationalisation strategy, avoiding disruptions from shocks like the pandemic.

COVID-19 arrived when the Brazilian machinery industry was facing serious structural problems associated with the neglect of long-term technological growth, and the damage was devastating: a humanitarian crisis. In our view, it shows the importance of establishing a business environment consistent with long-term sustainable development – consistent with upgrading and improving the resilience of value chains. Lastly, the pandemic revealed a positive side of the industry that can inspire the search for a national pact for inclusive development: the understanding among people involved in the value chain is essential to overcome the health, economic, political, and social crisis. Although the collaboration efforts vary depending on hierarchy levels, governance structures, and social responsibility, this solidarity feeling may multiply and guide the new normal.

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