

Drivers of employment change in Brazil in sectors by technological intensity: a structural decomposition analysis *

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Abstract

This article investigates the drivers of formal employment growth in Brazil during the 2010s, exploring the heterogeneity of human capital and technological intensity across sectors. Using input–output matrices, this study breaks down employment into contributions resulting from technological changes, labor productivity, and the structure of final demand in different subperiods. The results show that low-tech sectors and less-skilled workers were more affected by new economic factors, resulting in job losses. These changes were induced by increases in labor productivity and technological advances. In the last decade, demand growth, driven by household consumption, was the driver of job creation for workers with higher levels of human capital in practically all technological sectors, suggesting changes in the labor market with a bias toward qualification. To a lesser extent, demand for exports and fixed capital also contributed to employment growth in the economy.

Keywords: *labor market; human capital; technology; input–output; economic crisis; Brazil.*

JEL Classification: *C67; J20; O30; R10.*

1 Introduction

The Brazilian economy began the new century by reversing the trend of falling employment observed after the economic opening in the 1990s, largely due to the improvement of macroeconomic conditions and the expansion of exports (Macedo & Porto, 2021). Between 2003 and 2008, exports were the main driver of the country's growth, with an average annual growth rate of 7.7%. After the global crisis of 2007, the Brazilian government implemented countercyclical policies to maintain economic growth. This intervention resulted in a broad process of formalizing employment contracts, increasing the purchasing power of the population, and reducing socio-economic inequalities. In addition, public investments and productivity improvements also contributed to the

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Brazilian economy growing at an average rate of 3.5% per year until 2014 (Macedo & Porto, 2021; Magacho & Rocha, 2022). As a result, between 2003 and 2014, formal employment jumped from 29.5 million to 49.5 million, a remarkable increase of 67.8%. Workers who had completed a high school education and higher education also had considerable growth (over 80%), reaching 22.8 million and 9.3 million in total in formal employment, respectively.

However, starting in 2014, the Brazilian economy began to lose steam and experienced a significant slowdown in economic growth. Although there is no consensus on the exact causes of this economic crisis, it is widely accepted that it was the result of a combination of poor government interventions, lasting shocks to demand and supply, and loss of government credibility in conducting monetary and fiscal policies¹ (Barbosa, 2017). Between 2014 and 2016, the country's average growth rate fell to an alarming -2.3%. Although exports moved in the opposite direction, with a 2.3% increase, the agro-export model no longer presented as much potential to sustain production and employment growth in the medium and long term (Magacho & Rocha, 2022). In 2017, the unemployment rate reached levels of a depressed economy (13.2%), equivalent to 13.5 million unemployed people. Not surprisingly, informal work, which had previously declined, grew to 11.2 million in 2018 (Nassif, 2017).

This article aims to identify the drivers of the variation in formal employment in Brazil during the 2010s. The periods of economic growth (2010 to 2014) and recession (2014 to 2018) are considered to carry out a comparative analysis of the effects of different factors on the variation of employment by the level of human capital and technology intensity of the sectors. Using the input–output model as a framework for a structural decomposition analysis, this investigation seeks to identify the determinants of the variations in employment, taking into account the effects of general equilibrium. This method allows estimating the direct and indirect impact of the variations of each component of demand, as well as their potential impacts on the variations in employment due to multiplier effects. It also allows for estimating the effect of the increase in labor productivity and technological changes on employment.

By integrating endogenous factors of economic growth into input–output modeling, it is possible to analyze the Brazilian labor market from the perspective of the heterogeneity of human capital and technological intensity of sectors. This allows for a deeper examination of economic changes in the labor market (Acemoglu & Autor, 2011; Autor et al., 2003; Romer, 1990). Sectors with higher technological intensity usually require more skilled labor and have higher productivity and wages. On the other hand, sectors with lower technological intensity tend to have lower productivity and wages, but job availability is more elastic for less skilled workers (Acemoglu, 2002; Compagnucci et al., 2021). Examining employment variations across sectors by technological level is also important for identifying opportunities for economic growth and subsequently reducing unemployment. Sectors with higher technological intensity often have greater potential for productivity growth and innovation, which can lead to job creation and economic development (Hauknes & Knell, 2009). Another possibility is to identify ways to promote economic growth while ensuring social inclusion. Sectors with lower technological intensity tend to offer more opportunities for less skilled workers, providing them with a source of employment and income. Considering the differences between sectors, it is possible to inform economic planners which sectors offer more potential for this class of workers, enabling them to develop programs to facilitate their entry into the

¹In particular, it involves distortions in the economy caused by broad government intervention, including the implementation of interest rate cuts, price controls, targeted investments, and subsidies. Additionally, the sharp slowdown in the global economy, as well as the economic stagnation of major trading partners such as China and Europe, further exacerbated the economic crisis in Brazil (Barbosa, 2017; Magacho & Rocha, 2022).

formal labor market (Glomm & Ravikumar, 1992; Lima et al., 2020). Finally, sectors with higher technological levels tend to demand more qualified labor, requiring investments in training and education programs to ensure the availability of workers with the necessary qualifications to fill job positions (Acemoglu, 2002; Acemoglu & Restrepo, 2019).

Previous studies have also used input–output modeling to analyze labor market patterns and identify the factors driving employment changes in various economic contexts. Gregory et al. (2001) observed that demand growth and technological advances led to significant skill bias in the British labor market. Tin (2014) revealed that the main drivers of employment growth in the manufacturing sector during Malaysia’s industrialization were domestic and external demands. Carrascal Incera (2017) found that during periods of economic growth in the European Union, household consumption and exports were the main sources of job creation for young people, while productivity gains were the main source of unemployment. Madariaga (2018) that during Spain’s economic boom, demand changes acted as a key factor in employment growth in sectors and occupations that require more professional skills, while labor productivity gains partially offset this effect. Doan and Long (2019) also found that domestic and export demand expansion drove employment growth in China. Barba and Iraizoz (2020) further identified that internal demand was the engine of employment growth for women in the European Union, especially in public services sectors, while labor intensity had the opposite effect, especially in private services sectors. These changes led to a decrease in gender segregation levels in productive sectors.

In Brazil, input–output modeling and structural decomposition analysis have been increasingly used to examine changes in the labor market. Sesso Filho et al. (2010) found that trade liberalization led to a shift in employment from the agricultural and industrial sectors to the trade and service sectors. Perobelli et al. (2016) found that final demand was the main driver of job creation across almost all levels of education during the post economic opening period, while productivity had an inverse effect. Fiuza-Moura et al. (2016) found that technological changes during the 2000s created service sector jobs and eliminated commerce jobs. Catelan et al. (2021) found that the decrease in youth employment in the Brazilian economy was the result of an increase in overall labor productivity and a decrease in the level of utilization of this factor, compensated by increased household consumption, investment, exports, and government spending. Acypreste (2022) found that while technology led to increased unemployment, these losses were more than offset by creating new jobs due to the growth of demand in the Brazilian economy.

This study contributes to the literature by conducting a structural decomposition analysis of employment based on the level of human capital and technological intensity of sectors in Brazil during periods of economic growth and retraction. This empirical investigation is unprecedented for the Brazilian labor market and is based on consolidated evidence that shows that workers and industries can be heterogeneous in terms of skills, knowledge, and technology. Consequently, sectors and workers may be affected differently by economic transformations and innovations such as production automation, artificial intelligence, and robotization (Acemoglu & Autor, 2011; Hauknes & Knell, 2009; Lise & Postel-Vinay, 2020). Considering the analyses already done for the Brazilian economy, this empirical study advances the literature by disaggregating final demand to identify the effects of household and government consumption, gross fixed capital formation, and exports on the variation in registered employment by level of human capital. Moreover, this analysis provides important information about the transformations that the Brazilian labor market is going through and contributes to helping formulate policies for the growth of formal employment.

The remainder of the article is structured as follows. Section 2 presents the structural decomposition model of employment and the data used. Section 3 presents the empirical results for formal employment by level of human capital and sectoral technological intensity for Brazil. The final section provides a discussion and the main conclusions.

2 The model and data

2.1 Structural decomposition

Structural decomposition analysis (SDA) is based on intersectoral internal and external flows of inputs and outputs and demand model specifications to capture direct and indirect demand effects in all sectors. The basic structure of the SDA model consists of an input–output matrix, which represents the economic system with n productive sectors by technological intensity. This matrix denotes payments in monetary units between sectors in year (t), as well as intermediate inputs (x_{ij}) allocated in the production process of other goods. Columns (j) denote sectors that demand inputs, while rows (i) represent sectors that supply goods and services. Final demand (D) encompasses household consumption expenditure (C)² and government expenditure (G), gross fixed capital formation (K), and exports (E). Thus, the gross value added of each sector is determined by the sum of intermediate consumption and final demand (Barba & Iraizoz, 2020) From this structure, the Leontief demand model is expressed as follows:

$$X = (I - A)^{-1}D \quad (1)$$

where X is a (6×1) vector of sectoral production by technological intensity, I is an identity matrix (6×6), and A is a (6×6) matrix of technical coefficients, where each element a_{ij} is expressed by a fixed proportion of inputs used in the production process (x_{ij}/X_j), while $(I - A)^{-1}$ is the inverse Leontief matrix (L) with direct and indirect technical coefficients. These coefficients indicate, in monetary units, the production of sector (i) necessary to meet one unit of final demand. The above model can be simplified as $X = LD$.

To analyze changes in the labor market, five vectors of employment coefficients are constructed for each year $t \in \{2010, 2011, \dots, 2018\}$ by level of human capital, according to the following equation:

$$h_{iq} = H_{iq}/X_i \quad (2)$$

where the value of $q \in \{1, 2, \dots, 6\}$, with the sixth being the total formal jobs in the sector by technological intensity of the economy. As mentioned, the sectors $i \in \{1, 2, \dots, 6\}$, with the first five being the sectors by technological intensity, while the sixth is other sectors. The vector of employment by level of human capital (h_{iq}) is a proportion of the number of formal jobs at each level of qualification (H_{iq}) by the gross value of production of each sector by technological intensity (X_i).

Next, a matrix of employment generation by level of human capital is constructed, according to Equation (3). To measure it, first, the matrix \hat{h}_q is created, which is a diagonal matrix calculated based on the vector h_q . By multiplying the new matrix by the Leontief inverse, the matrix $G(\hat{h})$ is found (Perobelli et al., 2016).

²The variation in stock and consumption of philanthropic institutions has been added to household consumption.

$$G(\hat{h}_q) = \hat{h}_q L \quad (3)$$

The sum of the elements in each column of the matrix $G(\hat{h})$ equals the employment multiplier by human capital level (q) for each sector by technological intensity (i)³.

Given the objective of this empirical study to analyze the drivers of changes in employment by human capital level, the following equation is considered:

$$\Delta H = H_t - H_0 = \hat{h}_t L_t D_t - \hat{h}_0 L_0 D_0 \quad (4)$$

where 0 and t represent the initial and final years of each subperiod, including the initial and final periods of the study. To do so, the periods from 2010 to 2014, 2014 to 2018, and 2010 to 2018 are considered. The structural decomposition of employment variation for each subperiod follows the modeling approach of [Barba and Iraizoz \(2020\)](#), [Madariaga \(2018\)](#), and [Carrascal Incera \(2017\)](#).

The analysis focuses on identifying the drivers of changes in the Brazilian labor market. For the structural decomposition, matrices of employment variation by level of human capital were constructed as follows:

$$\Delta \hat{h} = \hat{h}_{qt} - \hat{h}_{q0}, \text{ with } q = 1, 2, \dots, 6. \quad (5)$$

Reorganizing Equation (4) and taking Equation (5), we can initially perform the structural decomposition of employment into three economic components (drivers):

$$\Delta H = \frac{1}{2} \left[\underbrace{\Delta \hat{h}(L_t D_t + L_0 D_0)}_{\text{Labor}} + \underbrace{(\hat{h}_t \Delta L D_0 + \hat{h}_0 \Delta L D_t)}_{\text{Technology}} + \underbrace{(\hat{h}_t L_t + \hat{h}_0 L_0) \Delta D}_{\text{Final Demand}} \right] \quad (6)$$

Equation (6) shows that the variation in employment between two periods is explained by the effects of labor factor intensity, technological changes, and final demand ([Barba & Iraizoz, 2020](#)). In this framework, technological changes represent any factors that cause changes in technical coefficients, such as technological innovations, technical substitution, and economies of scale ([Rose & Casler, 1996](#)). Next, final demand (D) is disaggregated into different components, such as household and government consumption, gross fixed capital formation, and export.

$$FinalDemand = (\hat{h}_t L_t + \hat{h}_0 L_0) \left(\underbrace{\Delta D^H}_{\text{Household}} + \underbrace{\Delta D^G}_{\text{Government}} + \underbrace{\Delta D^K}_{\text{Capital}} + \underbrace{\Delta D^E}_{\text{Export}} \right) \quad (7)$$

This same mathematical structure is also used to perform the structural decomposition of employment at aggregate and sectoral levels, aiming to present a more general overview of formal labor market changes in Brazil.

2.2 Structural change index

The Structural Change Index (SCI) is an estimate of the reallocation effect caused by various factors that influence employment and production in the Brazilian economy, such as technological transformations, foreign

³The employment multipliers by level of human capital and technological intensity of the sectors are provided in the supplementary material. The results of the production multiplier are also provided in the supplementary material. The indicators were calculated from open and closed input-output models.

trade, and changes in domestic demand. The *SCI* is calculated as follows:

$$SCI = \frac{1}{2} \sum |p_{it} - p_{it-1}|, \text{ with } 0 \leq SCI \leq 100 \quad (8)$$

where p_{it} and p_{it-1} represent the share of each sector in the total number of jobs in the economy in different periods, years t and $t - 1$. The use of the absolute value ensures that positive and negative values are not nullified when summed, while the sum is divided by two to avoid double counting. The SCI can range from zero (no structural change) to 100% (complete structural change in employment). Generally, the closer to zero, the greater the stability of the sectors' share of employment in the economy. On the other hand, the higher the value is, the greater the structural change and variation in the share of technology-intensive sectors. The same calculation is done for gross sectoral production (Sesso Filho et al., 2010).

2.3 Data

For this study, input–output matrices from 2010 to 2018 were used, constructed based on the methodology proposed by Guilhoto and Sesso Filho (2010). These matrices were produced using the use and resource tables from the *Instituto Brasileiro de Geografia e Estatística* (IBGE) and contain statistical information on intermediate production and consumption in monetary units of 128 products and 68 economic sectors. To ensure temporal comparability of the matrices, monetary values have been deflated with reference to the base year of 2010.

Next, the matrices of 68 economic sectors were grouped into six based on the OECD taxonomy proposed by Galindo-Rueda and Verger (2016). The technological intensity of the industries was defined by the fraction of private investment directed toward research and development (R&D) relative to the gross value of the sector's production. The industries were organized into sectors of low, medium-low, medium, medium-high, and high technological intensity⁴. A sixth category was also created to include industries that do not invest privately in R&D, such as the public sector, health, and education (Sarra et al., 2019).

The data on formal employment by level of education are from the *Relação Anual de Informações Sociais* (RAIS). From this database, information on employment relationships for approximately 670 activities at the class level is extracted. Then, these economic activities are associated with the 68 sectors of the input–output matrices, following the procedure provided by IBGE for matching the economic activities of the CNAE 2.0 and SCN⁵. Finally, employment is grouped by the level of human capital in sectors by technological intensity (R&D). For this purpose, a nomenclature similar to that of sectors by technological intensity is used for the distribution of formal employment by level of human capital. For this, employment distributed in ten levels of education is grouped into only five levels of human capital⁶: low (illiterate to 9th grade of elementary school), medium-low (complete elementary school and incomplete high school), medium (complete high school and incomplete higher education), medium-high (complete higher education) and high (master's and doctor's degrees).

⁴The distribution of the 68 industries in the input–output matrix, grouped into sectors by technological intensity, is available in the Appendix.

⁵For correspondence between activities in the *Sistema Nacional de Contas* (SNC) and the *Classificação Nacional de Atividades Econômicas* (CNAE 2.0), access IBGE.

⁶The classification of employment by level of human capital is also used in the following: *Atlas dos Estados Brasileiros*.

3 Results

This section presents the main empirical results of this study. The first part provides an overview of the growth of employment and production in sectors by technological intensity. The second part demonstrates the evolution of employment multipliers by the level of human capital. Finally, the structural decomposition of formal employment is analyzed.

3.1 Evolution of employment and production

This subsection presents the evolution of registered employment and gross production of sectors according to their level of technology for Brazil. The indicators used to evaluate the level and pace of growth were the ratio between the employment level of the sector and the average employment of all sectors and the ratio between the growth rate of employment in the sector and the average growth rate of employment of all sectors, respectively. Additionally, the same calculations were performed for sectoral production. Table 1 shows the average of these performance indicators of employment and sectoral production for the periods of growth (2010 to 2014) and retraction (2014 to 2018) of economic activity in Brazil.

[Table 1]

The level of growth reveals that the low-tech sector and other sectors (public sector) experienced significant employment growth during periods of economic growth and recession in Brazil. However, the growth rate shows that the high-tech and medium-high-tech sectors had above-average employment growth during the economic crisis. This result is directly related to the lower elasticity of labor substitution in technology-intensive sectors, as well as the sector's resilience to short- and medium-term economic contraction. The other sectors had significant employment growth in all periods, highlighting the labor market's dependence on public administration hiring. Except for the other sectors, the high-tech sector was the only sector to have an employment growth rate above average between 2010 and 2018.

Similarly, only the low-tech and other sectors (public sector) recorded significant production growth in all periods analyzed. During the economic slowdown, the high-tech, medium-high-tech, and medium-tech sectors also had above-average production growth, demonstrating relative resistance to the anticyclical movements of the economy. These industries also tend to accumulate more physical and human capital than low-tech industries, allowing them to adapt more quickly to ongoing economic and technological transformations (Aghion & Howitt, 1992).

In technological sectors where production is growing significantly, but the corresponding employment growth is not following the same pattern, there is evidence that labor productivity is increasing. This is particularly true in medium and medium-low technology intensity sectors, such as agriculture and manufacturing, which have had especially strong productivity increases in the last two decades. This suggests that production is outpacing demand for labor in these sectors (Acypreste, 2022). In particular, in the last decade, policies aimed at expanding access to higher education and professional qualification have reinforced the trajectory of productivity growth through an increase in the education level of the workforce (Casqueiro et al., 2020).

3.2 Sectoral employment multiplier

The employment multiplier is a measure of the ability of technology-intensive sectors to generate formal jobs for each level of human capital in Brazil. Table 2 shows the ratio of employment multipliers by level of human capital for various sectors. Workers with medium-low and medium levels of human capital have the highest proportions in sectoral multipliers. This indicates that fluctuations in domestic demand generate more jobs for workers with these qualification levels. Between 2010 and 2018, the proportions of medium, medium-high, and high levels of human capital increased in employment multipliers, while the proportion of lower levels gradually decreased in all technology-intensive sectors. This suggests that the expansion of the economy's demand is generating jobs in sectors that require more skilled labor. This result is in line with a process of increasing productivity in the economy with a bias toward human capital, where less skilled workers are being replaced by more specialized workers (Acemoglu & Autor, 2011).

In 2018, the high-tech sector had an employment multiplier of 50.65% for workers with medium-level human capital. This indicates that 50.65% of job opportunities generated by the increase in domestic demand would go to workers with this level of qualification. High-level and medium-high human capital held 1.15% and 31.38% shares in the employment multiplier, respectively. The low-tech sector created the majority of jobs for workers with middle- and lower-middle human capital, with 58.56% and 17.71% of the employment multiplier, respectively. As expected, other sectors, such as public administration, education, and health care, generate the most opportunities for highly skilled workers, at 2.63%. These sectors are the main demanders of highly qualified human capital in the Brazilian labor market.

[Table 2]

During the period of economic growth, there was a reduction in the employment multiplier in the low-tech sector for workers with low (19.3% to 14.84%) and medium-low (24.76% to 21.55%) qualifications. This reduction led to a relative participation of 11.51% and 17.71% in the employment multiplier of the low-tech sector in 2018. On the other hand, the increase in demand had a positive effect on the employment of workers with higher levels of human capital between 2010 and 2018. The medium-high level of human capital increased from 8.15% to 11.96%, while the high level increased from 0.13% to 0.26%. This trend of job creation for workers with higher levels of human capital is also observed in other sectors at all levels of technology, indicating that a process of labor productivity growth is taking place in Brazil. This shift in the composition of the workforce, favoring those with higher levels of human capital, demonstrates the ability of the Brazilian productive structure to adapt and incorporate new technologies (Acemoglu & Restrepo, 2019; Perobelli et al., 2016).

3.3 Structural decomposition analysis

Between 2010 and 2014, the Brazilian job market grew by 12.5% in the number of formal jobs, from 44.1 million to 49.5 million, with an average employment growth rate of 3% per year. The positive highlights were in the low-tech sector, with an increase of 15.76% (3.5 million jobs). However, due to the economic retraction between 2014 and 2018, employment fell by 5.93%, from 49.5 million to 46.6 million. The only sector to show positive employment growth during this period was "other" (public sector), with an increase of 111.2 thousand jobs. Between 2010 and 2018, the low-tech (1.62 million), high-tech (8.84 thousand), and other (1.46 million) sectors

had positive employment variations. In contrast, the medium-low and medium-high technology sectors lost 221 thousand and 205 thousand jobs, respectively. In the subperiod from 2010 to 2018, employment increased from 44.1 million to 46.6 million (5.82%), with an average growth rate of 0.75% per year⁷.

[Table 3]

Analyzing the sources of employment variation in aggregate terms, Table 3 presents the results of structural decomposition in subperiods. The variation in employment is divided into three main components: labor intensity, technological change, and final demand. Demand is further decomposed into household and government consumption, exports, and gross fixed capital formation to more precisely identify the drivers of employment growth in the Brazilian economy. Between 2010 and 2014, employment growth was due to the effects of demand and technology, offset by labor intensity. *Ceteris paribus*, the increase in demand created 23.65 million jobs. Of this total, household consumption was the main driver of employment growth (12.29 million). Technology increased employment by 0.08 million, while labor intensity eliminated 18.24 million jobs, indicating an increase in productivity. Overall, employment increased by 11.1% (5.5 million).

Between 2014 and 2018, the demand effect increased registered employment by 40.81 million, while the labor intensity effect decreased by 43.9 million. Technological change generated an increase of 0.19 million jobs, while the effect of exports doubled, creating 5.94 million jobs during the economic crisis. As a result, the total variation in employment was a 6.31% decrease, equivalent to a loss of 2.94 million jobs. From 2010 to 2018, the signs of the mentioned factors remained the same, although their magnitude increased. Technology, for example, increased employment by 0.36 million, while exports increased by 9.37 million. Final demand, led by household and government consumption, surpassed the use of labor in the Brazilian economy, resulting in an overall increase in employment of 5.5% (2.56 million).

Although the growth of technological unemployment is a reality in emerging markets, technological changes have actually increased employment in the Brazilian economy during the periods analyzed. [Acemoglu and Restrepo \(2019\)](#) explain this by arguing that the workforce has a comparative advantage in new and more complex tasks that arise with technological progress and economic transformations. If this comparative advantage is significant and the creation of new tasks is continuous, employment can increase or remain stable in the long term, even with the introduction of innovations in the production system. It is important to emphasize that job creation is one of the main macroeconomic factors that stimulates economic development; therefore, it is important that employment in the economy remains balanced with new technologies and is able to adapt to economic changes ([Sousa Filho et al., 2021](#)).

[Figure 1]

In Figure 1, the structural decomposition of employment variation by technological intensity sectors is shown. During the economic acceleration, there was a 13.6% increase in low-tech sector jobs in Brazil, equivalent to 3.5 million jobs. Household consumption generated an increase of approximately 35% in employment, while exports (7%) and government consumption (3%) also generated such increases. While the contribution of capital

⁷The evolution of employment in the economy and sectors by technological intensity is presented in the Appendix.

to employment growth was not higher than 10%, work intensity acted in the opposite direction, reducing employment in sectors by over 40%. A similar pattern continued throughout the period and in the two subperiods analyzed for the Brazilian economy.

During the economic recession, technical change created 320.2 thousand jobs in the low-tech sector, 72.7 thousand in the medium-high technology sector, and 142.7 thousand in other sectors. However, between 2010 and 2018, technological changes had mixed effects on job creation. Technical change generated jobs in the medium-high (36 thousand) and low (710 thousand) technology sectors and in other sectors (188 thousand) while eliminating jobs in the high (59.8 thousand), medium (258.4 thousand), and medium-low (255.3 thousand) technology sectors. The expansion of the components of final demand was able to sustain the growth of formal employment between 2010 and 2018. Employment increased by 2.7 million in the Brazilian economy during this subperiod.

[Figure 2]

The Structural Change Index (SCI) shows instability in the participation of technology sectors in both employment and production. Between 2010 and 2018, the SCI had a value of 2.28, meaning that the sum of variations in the sectors' participation in employment was 2.28%. During periods of economic acceleration and deceleration, the SCI for employment jumped from 1.49% to 1.96%. The SCI for production had a value of 2.94% during the period of economic growth and a lower value during the economic downturn (1.66%). In the subperiod from 2010 to 2018, the SCI for production reached 3.63% (Table 3). The evolution of the SCI for employment and production over time confirms instability and reinforces the results observed for the subperiods (Figure 2). In general, the instability identified with the SCI for employment and production reflects strong government intervention in the economy, mainly between 2010 and 2014, combining monetary policy with interest rate reductions and fiscal policy with investment expansion, subsidies, and price intervention (Barbosa, 2017; Magacho & Rocha, 2022).

3.4 Decomposition of employment by level of human capital

This section examines the structural changes in formal employment in Brazil during periods of economic growth and recession, exploring the heterogeneity of human capital across sectors by technological intensity. Detailed information on jobs by level of human capital in each sector by technological intensity can be found in the Appendix.

Employment opportunities for highly skilled workers have increased in Brazil. Between 2010 and 2018, the number of jobs requiring a high level of human capital rose from 212.8 thousand to 508.1 thousand, an extraordinary growth of 138.7%. Jobs for medium and medium-high human capital also increased from 20.26 million to 24.62 million (21.5%) and from 7.06 million to 10.22 million (44.8%), respectively. In contrast, employment requiring low to medium-low levels of human capital decreased from 9.29 million to 6.80 million (-26.8%) and from 7.23 million to 4.46 million (-38.3%). This evidence suggests a trend toward the greater accumulation of qualified human capital, enabling the Brazilian economy to adapt to economic and technological transformations. According to Perobelli et al. (2016), the persistence of this phenomenon is a key factor in the ability to incorporate technology into production processes, as well as in competitiveness and latent potential for eco-

conomic growth. These results confirm this trajectory and indicate that Brazil continues to advance based on an endogenous model of economic growth.

Figure 3 presents the structural decomposition of employment for workers with low levels of human capital. The total variation shows a significant decrease in low-skilled employment across sectors and periods analyzed. In absolute terms, approximately 1.1 million jobs were eliminated between 2010 and 2014 and 1.7 million between 2014 and 2018, resulting in a total reduction of 2.8 million jobs over the entire period. All sectors experienced a decrease in employment for low-educated workers, but the decline was most pronounced in the low-technology sector, which saw a reduction of 483.2 thousand jobs between 2010 and 2014 and 1.1 million between 2014 and 2018. Excluding the low technology sector and other sectors (such as the public sector), the average reduction in employment for this group of workers was 75.9 thousand between 2010 and 2014, 100 thousand between 2014 and 2018, and 178 thousand between 2010 and 2018.

[Figure 3]

The reduction in employment for less skilled workers is driven by the intensity of labor utilization, which decreases on average by 55% to 60% across sectors, indicating that sectoral production is growing more rapidly than the hiring rate. This result suggests that labor productivity is increasing in less technology-intensive sectors. With regard to the low-technology sector, the reduction in employment is compensated by demand growth, with exports and household consumption dominating in each subperiod, representing an average of 7% and 30%, respectively. Technology also increased employment in the low-technology sector and other sectors (such as the public sector) during all subperiods, although the effect was not greater than 5%. In contrast, in the medium-technology sector, technical changes could reduce employment by up to 10%, as observed during the economic growth period.

One possible explanation for this phenomenon in Brazil is the widespread increase in the level of education of the workforce due to public policies aimed at decentralizing and expanding access to higher education. These policies have matured in recent years and are changing the labor market, with a bias toward skilled labor (Casqueiro et al., 2020). This process is also leading to a reduction in contracting for low-skilled workers due to their lower adaptation to technological innovations and the industries' need for more specialized labor to meet their new demands (Acemoglu & Restrepo, 2018). As a result, the workforce is becoming increasingly well-educated, leading to higher productivity in sectors.

[Figure 4]

When analyzing the medium-low level of human capital, it is possible to notice that the labor factor was mainly responsible for the reduction in job opportunities (Figure 4). Between 2010 and 2018, the employment of this group suffered a negative variation of 2.5 million, with 283.1 thousand between 2010 and 2014 and 2.2 million between 2014 and 2018. Except for the low-technology sector, all other sectors showed a reduction in employment for this type of human capital during economic growth (2010 to 2014). The medium-low technology sector eliminated approximately 136.1 thousand jobs. On the other hand, the low-technology sector generated 51.3 thousand jobs, representing an increase of 0.9%, driven mainly by household consumption (30%), exports (5%), and capital (10%). However, job creation in this sector could have been even greater if it were not for the negative effect of the labor factor, which contributed to a 50% reduction in jobs.

This result highlights the decreasing demand for workers with lower levels of education in the Brazilian economy, even in sectors with medium-low technological intensity. Between 2014 and 2018, there was a significant retraction in employment for workers with medium-low levels of qualification, especially in the low (1.3 million) and medium-low (301 thousand) technology sectors. From 2010 to 2018, all sectors of the economy experienced a reduction in employment for workers with this qualification. As evidenced thus far, the growth of labor productivity is the main driver of the reduction in job opportunities for workers with low and medium-low professional qualifications.

[Figure 5]

Figure 5 highlights the employment decomposition for medium-skilled human capital. From 2010 to 2014, Brazil experienced an increase of 4.45 million jobs for this educational level, with all sectors showing employment growth during this period. The sectors that generated the most jobs were low (3.3 million), medium-low (435.8 thousand), and medium (122.1 thousand) technology. The driving forces for employment in low-tech sectors were primarily household consumption (30%), capital (10%), and exports (5%), offset by a decrease in labor intensity (-32%). The medium-low technology sector presented a pattern very similar to the previous sector. In the medium technology sector, household consumption (31%), exports (18%) and capital (10%) increased employment for this group, while technology (-10%) and labor intensity (-25%) decreased. In absolute terms, exports created 81 thousand jobs out of the 291.7 thousand created for this group due to demand variation in the medium technology sector. It is also worth noting the effect of capital, equal in magnitude to household consumption, in generating jobs in the high-tech sector, with 20% per each (105 thousand jobs). Although small in effect, technical change contributed to the generation of medium-skilled human capital jobs in the low-tech (96.1 thousand) and high-tech (9.2 thousand) sectors. Additionally, other sectors saw an increase of 468.8 thousand job openings for this qualification level (8.5%), with growth driven by government consumption (33%).

During the economic recession from 2014 to 2018, only the low-tech sector was able to create jobs for medium-skilled workers (179.4 thousand), thanks to the effects of technological growth (1%) and demand (50%) outweighing the decrease in labor intensity (-50%). Excluding the low-tech sector, the remaining sectors experienced a reduction in employment for this group, with the medium-high (113 thousand) and high-tech (87.8 thousand) sectors being the most affected. The high-tech sector's job reduction was driven by both labor intensity (-55%) and technical change (-5%), while the main factor of unemployment in the medium-high-tech sector was changes in work requirements (-60%). Despite the decrease in employment, productivity increased in these sectors during the economic crisis. From 2010 to 2018, the high- and medium-high-tech sectors eliminated approximately 100 thousand jobs, while other sectors generated approximately 4.46 million jobs for medium-skilled workers.

[Figure 6]

Figure 6 shows the employment decomposition for medium-high skilled workers. Employment in this group increased by 2.27 million from 2010 to 2014 and by 896.7 thousand from 2014 to 2018, with a total increase of 3.16 million jobs. All sectors had job growth in the first subperiod, with the public sector adding 1.1 million jobs. The lower effect of work intensity was important for job growth, particularly in technology-intensive sectors. For example, in medium-high technology sectors, work intensity had a negligible effect, while in medium-low

technology sectors, it was less than 10%. Job growth in low and medium-low-technology sectors was driven by household consumption (45% and 40%), capital (10% and 4%), and exports (7% and 11%). In medium and medium-high-technology sectors, household consumption (35% and 45%), exports (20%), and capital (12% and 25%) were the main determinants, while in high-technology sectors, household consumption (30%) and capital (22%) were the main drivers.

The low-tech sector generated 661.5 thousand jobs for this type of human capital between 2010 and 2014, while the medium-low (219.1 thousand) and high-tech (114.4 thousand). In the low and medium-low technology sectors, employment growth was determined by household consumption (45% and 40%), capital (10% and 4%), and exports (7% and 11%). In the medium and medium-high technology sectors, household consumption (35% and 45%), exports (20%), and capital (12% and 25%) were the primary determinants of employment growth. Finally, in the high-tech sector, household consumption (30%) and capital (22%) were the main drivers.

During the economic downturn, job creation remained strong for workers with medium-high skill levels across all sectors, as evidenced by employment developments. The low technology sector generated 330.6 thousand jobs, equivalent to a variation of 12%, while the medium-low and high technology sectors generated approximately 38.1 thousand (5.4%) and 32.7 thousand (7.85%) jobs, respectively. Demand accounted for approximately 55% of the change in employment in the low-tech sector, while it was 51% in the lower-middle and high-tech sectors. Household consumption and exports were the main drivers of job growth in low-tech sectors, while capital prevailed over export demand at higher levels. From 2010 to 2018, the average change in employment of workers with a medium-high level qualification was 32.2%. Overall, the growth of a skilled workforce is essential to sustain productivity, innovation, and competitiveness in the Brazilian economy.

[Figure 7]

For workers with high levels of human capital (those with master's and doctor's degrees), the structural decomposition presents a similar pattern to that of workers with medium-high qualifications for periods of economic acceleration and deceleration (Figure 7). Between 2010 and 2014, there was an increase in employment for this group of workers (134.8 thousand), with job opportunities concentrated in other sectors (111.7 thousand). The driver of employment growth in this sector is government consumption (72%). It is important to note that this workforce is mostly hired by the public sector and educational institutions in Brazil, which is why it is concentrated in other sectors. The other job positions created (23 thousand) are distributed among the low (10.6 thousand), medium-low (5.7 thousand), and high (4.7 thousand) technology sectors. Unlike what has been observed thus far, labor intensity positively contributed to employment growth for the more qualified workers in the medium-low (33%), medium (18%), and medium-high (8%) technology sectors, which indicates an increase in productivity. Despite this, the positive evolution of employment in technological sectors continued to be largely determined by demand structure, especially from household consumption.

Despite the economic crisis between 2014 and 2018, 160.4 thousand jobs were created for workers with a high level of human capital. The other sectors (public sector) created approximately 84% of job opportunities, with growth driven by government consumption (48%). Unlike the previous subperiod, the intensity of work reduced highly qualified employment in all sectors, meaning that labor productivity increased. *Ceteris paribus*, technical change reduced jobs in the high-tech sector by 8.6 thousand for this group. From this perspective, the relative contribution of exports to job creation for these workers has ranged from 10% in the high-tech sector to

22% in the medium-high technology sector. Surprisingly, the effect of exports was equivalent to that of household consumption in the medium and medium-high-technology sectors for this group of workers. However, in absolute terms, job creation is still very small. In contrast, in the medium-low and low-technology sectors, household consumption continued to be the main determinant of employment growth. Between 2010 and 2018, approximately 295.2 thousand jobs were created, but their generation remained concentrated in other sectors (83%). Furthermore, the effect of the determinants remained similar to the previous period, that is, with the structure of demand increasing job opportunities, while technology and work intensity decreased.

4 Discussion and Conclusions

This article presents a comprehensive analysis of changes in registered employment in sectors with different levels of technological intensity in Brazil during the 2010s. The analysis is carried out considering the recent subperiods of acceleration (2010 to 2014) and deceleration (2014 to 2018) of the economy. The structural decomposition method was used, which considers components of final demand, technological changes, and labor market factors to identify drivers of employment variation. The analysis explored the heterogeneity of human capital and sectoral technological intensity to provide a detailed overview of transformations that have occurred in the Brazilian labor market over the past decade. Thus, the main results and their implications for the economy are presented below.

During the economic downturn, technology-intensive sectors experienced higher employment growth, while low-tech sectors performed better during economic acceleration. However, the low-tech sector is vulnerable to exogenous shocks, and job concentration in this sector could hinder Brazilian economic growth. To reduce job concentration in low-tech sectors and promote job creation in high-tech sectors, the government should implement investment programs in education and infrastructure, encourage innovation through tax incentives and subsidies, diversify industries and sectors, and attract foreign investments (Aghion & Howitt, 1992; Grossman & Helpman, 1991; Magacho & Rocha, 2022).

The multipliers reveal that job creation resulting from domestic demand expansion in recent years was directed toward workers with medium to high-level human capital in all sectors by technological intensity. In contrast, employment for workers with lower levels of human capital consistently decreased in the last decade. The growth in the level of workforce education has induced changes in the labor market with a skill bias, so even low-tech sectors are hiring workers with higher levels of specialization to increase productivity and adapt to new economic factors. This result indicates that the economy is accumulating more qualified human capital in its production processes, thus expanding its competitiveness and capacity to generate and absorb innovations to sustain increasing returns in production. This process has been essential to reduce unemployment, improve income distribution, and increase well-being in the Brazilian economy (Perobelli et al., 2016).

By decomposing the change in employment, it was possible to observe, through the labor factor, the productivity gains of the Brazilian economy, both in the growth period (2010 to 2014) and the recession period (2014 to 2018). Productivity gains also occurred in virtually all sectors by technological intensity. The increasingly latent technological unemployment, particularly in emerging markets, was not confirmed at the aggregate level for Brazil. In truth, technological changes modestly increased employment levels, which means that technical progress induced the creation of new activities and tasks that, in turn, translated into new job opportunities

(Acemoglu & Restrepo, 2018). Although exports are of great importance to the Brazilian job market, in the most recent decade, job creation has been dominated by the expansion of household and government consumption. The growth of exports oscillates between the second (2014 to 2018) and third (2010 to 2014) most important factors in the structure of final demand for the generation of formal jobs. However, according to Magacho and Rocha (2022), this engine lost strength between 2013 and 2016 due to the fall in commodity prices and in recent times has not been able to sustain the growth of production and employment at the levels observed in the early 2000s.

Household consumption is the driving force behind the growth of employment in all the technological sectors of the Brazilian economy due to its large domestic market. Among the components of the final demand structure, the effect of gross fixed capital formation is greater than that of exports in the generation of jobs in the high-technology sector. On the other hand, demand for exports contributes more to the creation of jobs in basic sectors, that is, in medium to low-technology sectors. Between 2010 and 2018, the effects of exports were also higher than those of fixed capital in the generation of jobs in medium-high technology sectors. This shows that demand for exports is contributing increasingly to the growth of employment in nonbasic sectors of the economy. Maintaining this pattern is essential for the decentralization of jobs in low-technology sectors and, consequently, for sustainable economic growth in the medium and long term.

The main conclusions on the decomposition of employment by level of human capital in sectors by technology intensity are as follows:

- Sectors with lower technological intensity and less qualified workers are the most affected by recent economic changes in Brazil, resulting in significant losses of formal employment. In contrast, employment opportunities have grown in more technology-intensive sectors and for more qualified workers. Notably, the Brazilian economy follows a trend of productivity growth with a human capital bias.
- Work intensity is the main factor reducing employment, particularly for workers with lower human capital. However, during periods of economic growth, it has a positive effect on job creation for more qualified workers, leading to an overall increase in productivity in the Brazilian economy.
- Technological change had small and mixed effects on the variation in employment. In low-technology sectors, technological change increased the employment of more qualified workers. Except for the period of economic growth between 2010 and 2014, technical progress reduced job opportunities for all levels of human capital in more technology-intensive sectors, probably due to the automation of production processes⁸. In general, technological unemployment is increasing; however, this is more than compensated for by the growth in domestic demand.
- Within the structure of demand, household consumption is the main driver of employment growth for virtually all skill levels, both during periods of economic growth and contraction, due to the large domestic market. To a lesser extent, demand for exports and fixed capital also contributed to job growth across all skill levels.

⁸According to a survey by the [Machine Learning Laboratory in Finance and Organizations](#) (LAMFO) at the University of Brasília (UNB), by 2026, 54% of jobs with a signed contract in Brazil (30 million) could be filled by robots and computer programs, which would result in higher unemployment rates.

In conclusion, the Brazilian economy experienced an increase of 2.56 million formal jobs between 2010 and 2018, with an average annual growth rate of 0.75%. To sustain this growth, it is important for the government to promote stimulus to demand components, especially household consumption, through the resumption of public investments in infrastructure. In the short term, it may be necessary to remove infrastructure investments from the government spending ceiling to enable this initiative (Magacho & Rocha, 2022). This measure can help to regain the pace of production and employment growth in Brazil.

5 Supplementary Material

The [Online Appendix](#) of the article contains descriptive statistics and the result of structural decomposition. [Supplementary Material](#) contains additional results and information of secondary interest to readers and policymakers.

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Table 1: Average of the level and pace of growth indicators for employment and production (%)

Sector	High		Medium-High		Medium		Medium-Low		Low		Other sectors	
	GL	GR	GL	GR	GL	GR	GL	GR	GL	GR	GL	GR
Employment												
2010-2014	13	68	21	-27	17	39	73	27	314*	130*	163*	100*
2014-2018	12	156*	18	131*	15	94	69	65	315*	44	171*	209*
2010-2018	13	112*	19	52	16	66	71	46	314*	87	167*	154*
Production												
2010-2014	20	99	24	7	15	102*	87*	67	337*	109*	117*	116*
2014-2018	19	119*	19	120*	13	158*	78	135	343*	91	128*	95*
2010-2018	20	109*	22	64	14	130*	82*	101	339*	100*	123*	105*

Notes: Level of Growth (GL) and Pace of Growth (GR) indicators by sectoral technological intensity. * Significant growth: (GL>80) and (GR>100).

Table 2: Proportion by level of human capital of sectoral multipliers of formal employment (%)

Sectors	Human capital levels														
	High			Medium-High			Medium			Medium-Low			Low		
	2010	2014	2018	2010	2014	2018	2010	2014	2018	2010	2014	2018	2010	2014	2018
High	0.60	0.84	1.15	20.92	26.32	31.38	50.11	50.99	50.65	16.64	13.5	10.47	11.73	8.35	6.35
Medium-High	0.17	0.23	0.35	10.10	12.93	15.37	50.13	54.29	58.23	22.90	19.62	15.92	16.69	12.93	10.12
Medium	0.12	0.17	0.25	7.63	9.29	11.67	47.69	53.42	58.26	25.09	22.01	18.02	19.46	15.10	11.79
Medium-Low	0.13	0.21	0.31	8.53	11.16	13.24	46.36	51.72	56.38	24.85	21.37	17.71	20.13	15.54	12.36
Low	0.13	0.17	0.26	8.15	9.81	11.96	47.65	53.64	58.56	24.76	21.55	17.71	19.3	14.84	11.51
Other sectors	1.19	1.77	2.63	31.32	36.01	39.32	42.37	42.69	42.98	14.17	11.86	9.17	10.95	7.66	5.89

Table 3: Structural decomposition of employment at aggregate levels (in millions)

Economic periods	2010-2014	2014-2018	2010-2018
Labor	-18.24	-43.94	-69.84
Technology	0.08	0.19	0.36
Demand	23.65	40.81	72.04
Export	2.17	5.94	9.37
Government	5.95	10.92	19.33
Household	12.29	21.05	37.07
Capital	3.24	2.90	6.27
Total variation	5.50	-2.94	2.56
Total Employment in % (Δ)	11.1	-6.31	5.50
Structural Change Index (SCI)			
Employment in %	1.49	1.96	2.28
Production in %	2.94	1.66	3.63

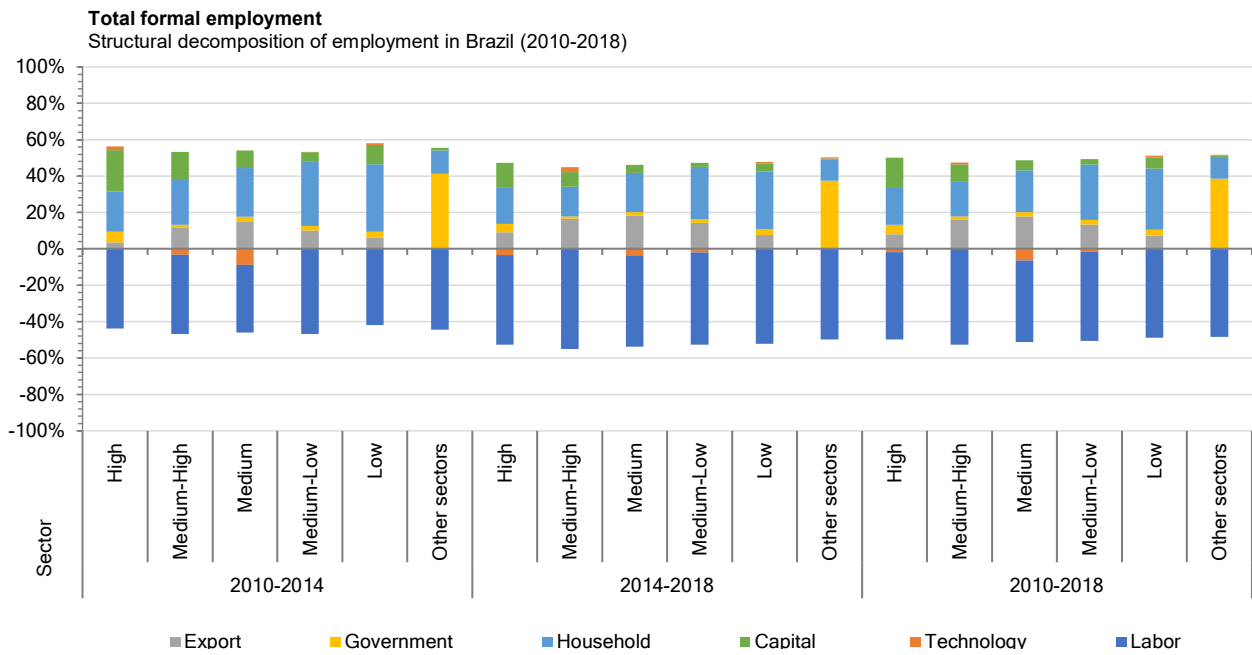


Figure 1: Structural decomposition of formal employment by sectors by technological intensity

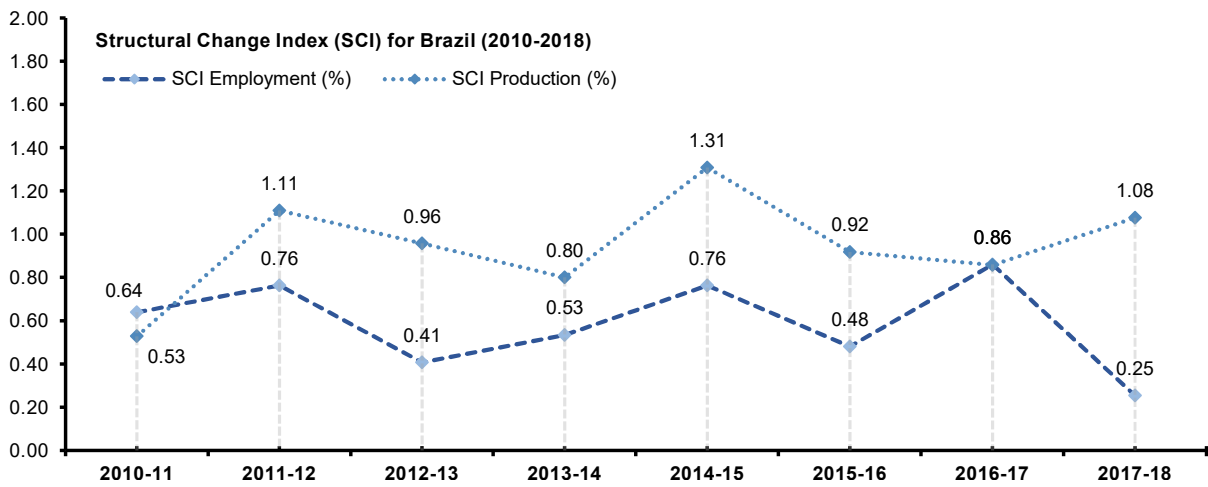


Figure 2: Structural Change Index (SCI) for Brazil (2010-2018)

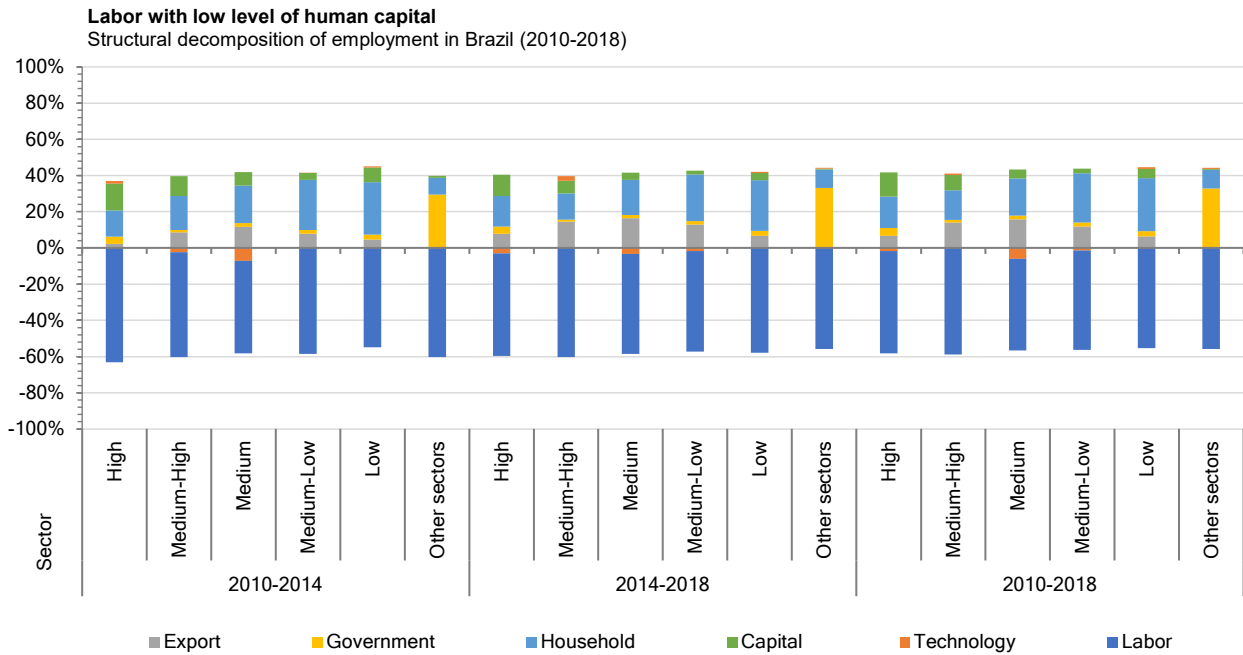


Figure 3: Structural decomposition of employment for low level of human capital

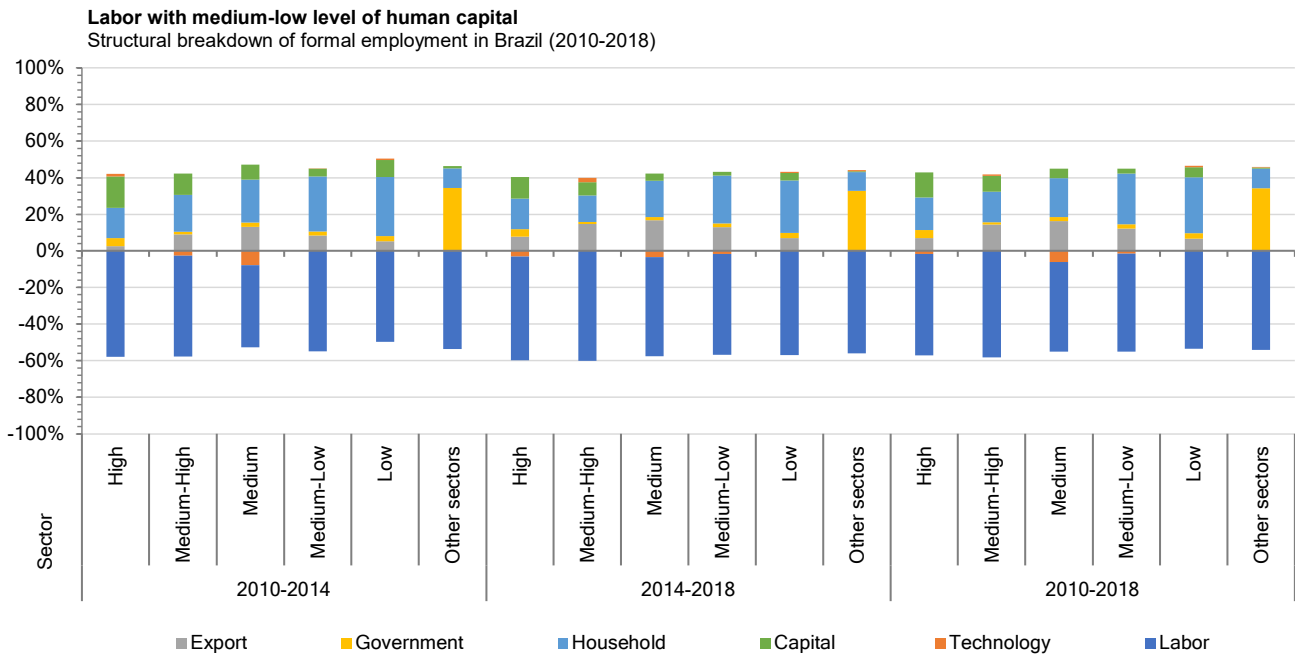


Figure 4: Structural decomposition of employment for the medium-low level of human capital

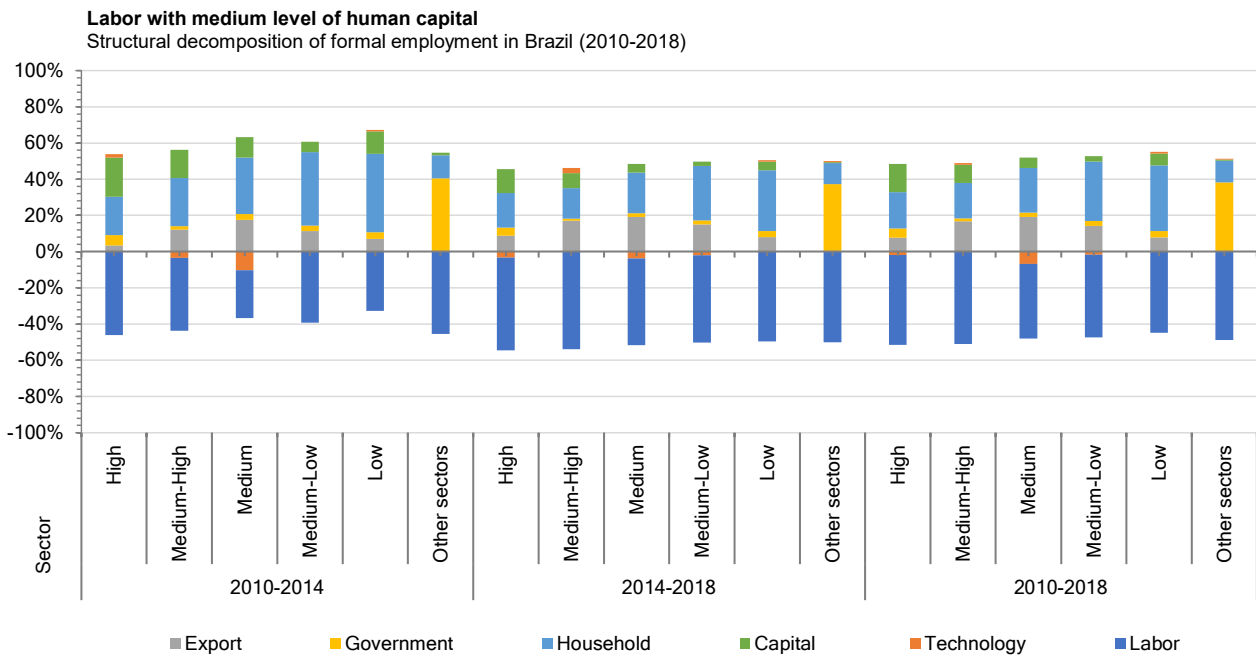


Figure 5: Structural decomposition of employment for the medium level of human capital

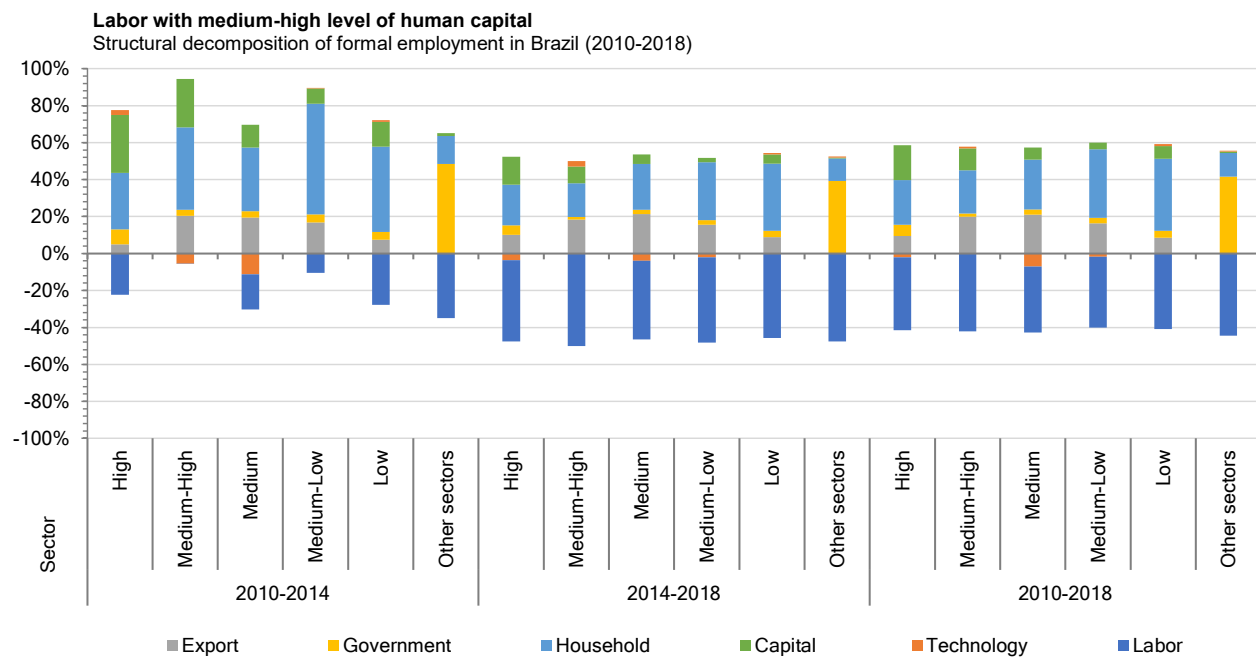


Figure 6: Structural breakdown of employment for the medium-high level of human capital

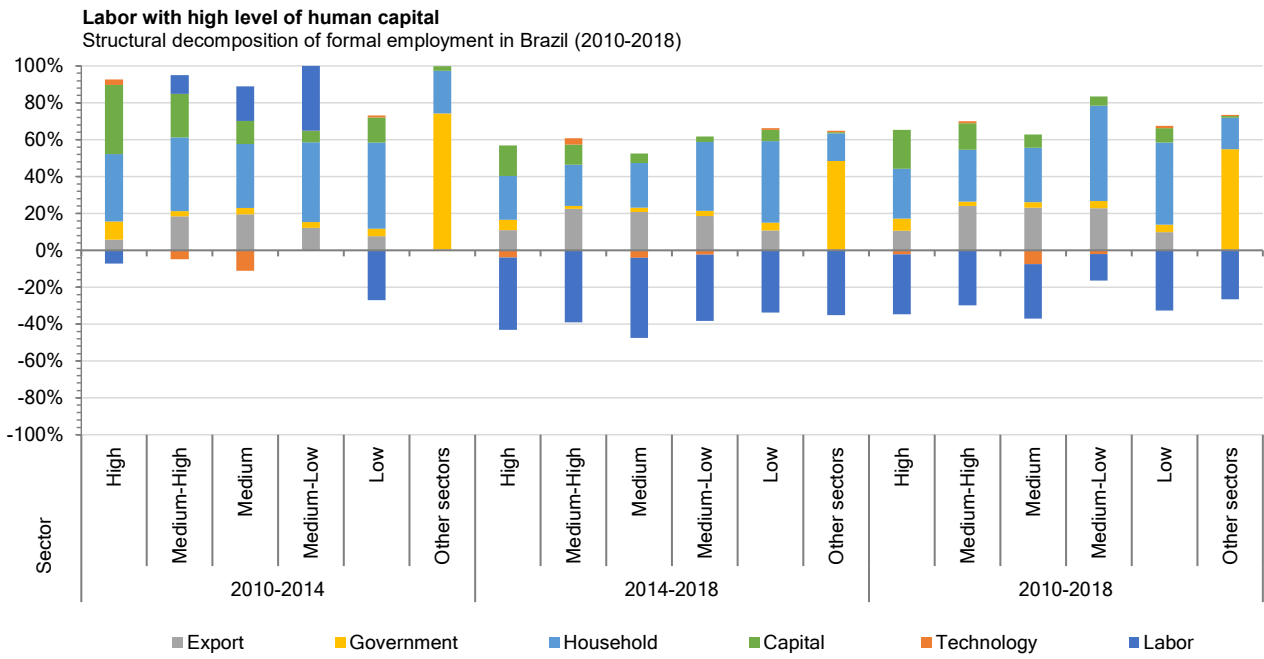


Figure 7: Structural decomposition of employment for high level of human capital