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STEM and International Trade in a Gender Perspective: The Cases of Brazil, Chile and Mexico

STEM y comercio internacional en clave de género: los casos de Brasil, Chile y México

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Abstract

The development of STEM (Science, Technology, Engineering, and Mathematics) careers in Latin America plays a critical role in fostering technological progress and innovation, thereby enhancing economic growth and competitiveness through trade, which, in turn, stimulates investments in R&D. This study explores the influence of economic opportunities presented by international trade on the gender gap among STEM-trained professionals. The findings reveal that exports of high-value-added services contribute positively to the labour market inclusion of women. Despite this progress, gender segregation continues to be a major barrier to bridging the gender gap, indicating a persistent adherence to traditional gender roles.

Keywords: Gender gap; international trade; employment; gender roles; technology intensity; Latin America.

Resumen

El avance de las carreras STEM (Ciencia, Tecnología, Ingeniería y Matemáticas) en Latinoamérica es clave para el desarrollo tecnológico y la innovación, potenciando la economía y la competitividad a través del comercio, que fomenta la inversión en I+D. Este estudio examina el impacto de las oportunidades económicas del comercio internacional en la brecha de género de los profesionales formados en STEM. Los resultados señalan que las exportaciones de servicios de alto valor añadido favorecen la inclusión laboral de las mujeres. No obstante, la segregación de género sigue siendo un obstáculo significativo para cerrar esta brecha y manifiesta una persistencia de los roles de género.

Palabras clave: Brecha de género; comercio internacional; empleo; roles de género; intensidad tecnológica; Latinoamérica.

JEL Classification/ Clasificación JEL: F14; J16; J21; J78.

1. Introduction

According to UNESCO (2019), in Latin America women represent less than 30-40% of total enrolments in STEM (science, technology, engineering, and mathematics) fields. This underrepresentation extends to the research domain, highlighting a persistent gender disparity in professions with the highest value-added and significant potential for economic progress in the region. STEM fields play a pivotal role in Latin America's development, as fostering high technology-intensive and knowledge-intensive economic activities is crucial for transitioning from economies reliant on the exploitation and export of raw materials to more diversified economies, emphasizing industry and advanced services. This transition is vital for enhancing the region's economic resilience, diminishing its vulnerability in global markets, and increasing its competitiveness in international trade. Nevertheless, promoting STEM must confront the substantial gender gap within these fields. An essential aspect to consider for STEM improvement and narrowing the gender gap is the economy's dynamism, especially through foreign trade in high value-added sectors. This could serve as a catalyst for high-tech and knowledge-intensive sectors, which have a notably high concentration of STEM occupations.

Nevertheless, both the gender gap in STEM disciplines and its interconnection with foreign trade in Latin America remain largely unexplored in academic literature. Regarding the former, while there is a large body of qualitative research highlighting the persistent gender gap in women's participation in STEM fields and identifying key socio-cultural determinants, many studies fall short of examining the implications of these factors on the region's economic development. Concerning the latter, although the nexus between the gender gap and foreign trade is well-documented in scholarly works, its application to the Latin American scenario, particularly in relation to STEM fields and sectors classified by their technological and knowledge intensity, is notably limited, if not altogether absent.

The aim of this paper is the exploration of the interaction between the gender gap in STEM disciplines and international trade in Latin America. This analysis is divided into several specific objectives: first, it examines the evolution and role of STEM disciplines in international trade in the Latin American context. Second, it examines the participation of women in STEM jobs within the labour market, assessing their representation in these fields and determining whether high value-added exports act as a factor mitigating the gender gap in STEM fields.

Regarding the methodology, the analysis begins with a quantitative approach, utilizing microdata from surveys on living conditions across various countries. For Brazil, the *Pesquisa Nacional por Amostra de Domicílios* (PNAD) is employed; for Chile, the *Encuesta de Caracterización Socioeconómica Nacional* (CASEN) is used; and for México, the data source is the *Encuesta Nacional de Ingresos Gastos de los Hogares* (ENIGH). This strategy enables an estimation of gender participation in STEM disciplines. This dataset is then augmented with international trade data from the *Trade in Value Added* (TiVA) database, 2023 edition, provided by the OECD. Specifically, we examine exports of domestic value-added (DVA) categorized by their technology and knowledge intensity. Additional pertinent variables are sourced from The World Bank. To evaluate the impact of these variables on the gender gap in STEM fields, we apply various econometric models using panel data for our estimations. The choice of these three countries is justified firstly by their representativeness for the Latin American economy as a whole: according to Economic Commission for Latin America and the Caribbean, Brazil, Chile and Mexico accounted for around 63% of the region's GDP in 2023. Secondly, because of the size of their employment statistics, which include a broad breakdown of different occupations and are standardised across the three cases. Finally, it can also be justified on the basis of previous literature, where these three countries have already been used as a basis for analysing social and economic dynamics in Latin America and the Caribbean (Aulakh et al., 2000; de Mello and Moccero, 2011; Mellado et al., 2012; Pamplona et al., 2016).

This work offers several contributions. First, it improves on the existing literature by providing a study on the relationship between the gender gap and international trade in STEM. Furthermore, it examines how economic opportunities arising from foreign trade in value-added might be distributed in a gender-biased way within the Latin American context, due to embedded cultural barriers.

The paper is organized in four sections, following this Introduction. Section 2 reviews the most relevant literature on STEM and its link with the gender gap and foreign trade in Latin American. Section 3 outlines the main data sources and the methodology employed. Section 4 presents and discusses the key findings of the research. Finally, Section 5 summarizes the main conclusions.

2. Literature review

The global context presents a significant challenge in terms of women's involvement in STEM fields and the Information and Communication Technologies (ICT) sector. These competencies are increasingly recognized as crucial, as evidenced in the "Future of Jobs 2020 Report," which underscores the significance of e-learning and digital skills amidst the pandemic and the fourth industrial revolution (Siekmann, 2016; World Economic Forum, 2020).

Despite this, female participation in education within these fields remains low, potentially perpetuating the gender gap across various professions and yielding lower educational returns in the medium term. Moreover, this situation perpetuates the dominant role of men in the most relevant activities regarding value generation in current markets (Delgado Cadena, 2020; Rodrīguez and Nājera, 2015).

This sexual segregation between economic activities has been explained on several occasions by differences in educational performance and aspirations between boys and girls in STEM. Gender segregation is analysed not only in the labour market, but also in education, especially given that choices made in the early stages of education have a direct impact on choices made in higher education and later in the labour market. In this sense, the results of educational achievement surveys show that women are particularly good at reading, while men are particularly good at mathematics. This, together with gender stereotypes, is an additional factor in the gender gap in STEM occupations. However, these differences in cognitive skills are revealed to be small and, to a large extent, the result of the specific sociocultural context –the family– and general –the country's level of development. In other words, these differences are largely due to social roles and gender stereotypes (Reilly, 2012). It has also been found that these early differences permeate into further stages of life, reinforcing gender differences (Maurer, 2011).

In the Latin American context, educational systems have failed to provide equitable and quality education, even women with similar levels of education to men receive lower wages, which perpetuates existing inequalities (Atal et al., 2009; Ñopo et al., 2010). In addition to differences in education, there are several factors that, according to Esteve et al. (2022), should be taken into consideration to understand the gender gap in this context. First, the high level of informality in the labour market, which significantly influences household structure and family formation patterns. Second, violence, in a broad sense, including forced displacement and violence against women. And third, the role of the *extended family*, which plays an important role in the region, serving as an essential support network in contexts of scarce social protection and in those regions with greater economic challenges. It is also noted that within the family, different roles are articulated according to gender stereotypes. In addition to these factors, Desposato and Norrander (2009) also highlight factors such as the inclusion of women in decision-making positions and the level of political freedoms in each territory.

Regarding female participation in STEM fields, the literature points out several access barriers, mostly of a sociocultural nature, such as "personal preferences, stereotypes, lack of role models, and cultural norms impact women's choices in higher education, while gender-biased recruitment, hiring and evaluation processes, restrictive regulations and norms, exclusion from networks, male-dominated culture, and work-family" (Tacsir et al., 2014, p. 25). Moreover, women face additional barriers such as lack of access to information, funding, poor institutional support, and low professional recognition (Arredondo Trapero et al., 2019; Marinova et al., 2022; Osorio et al., 2020; Verdugo-Castro et al., 2021).

Another relevant factor in the analysis of the gender gap is foreign trade. Since the late 1990s, international trade has been studied as an element leading to a reduction or increase in inequalities, including gender disparities. Initially, greater trade openness can lead to a situation of greater gender equality to the extent that external integration leads to an overall increase in employment levels (Almasifard, 2018; Al-Nimri et al., 2023; Benguria and Ederington, 2023; Black and Brainerd, 2004; Sepehrivand, 2017). To the extent that the available labour force is mostly female, a relatively higher increase in the number of female employees could be expected. However, these positive effects of integration into foreign markets resulting from a higher overall level of occupation are not clear, insofar as the gender gap needs to be understood from a multidimensional perspective (Tekgüç and Akbulut, 2022; Vicente and Muñiz, 2021; Zhang et al., 2022).

Aguayo-Téllez (2012) provides an interesting literature review on this topic, which also includes some contributions analysing the Latin American context. The results show that the trend towards trade liberalisation and the promotion of FDI inflows have created new employment opportunities, especially in activities that require a specific skill level. With regard to the gender gap, income inequality has decreased. On the employment side, however, inequalities have increased due to pre-existing differences in educational attainment between the sexes (Artecona and Cunningham, 2002; Villalobos and Grossman, 2008). Seguino (2006) has taken a broader approach by considering not only measures of employment but also well-being through health and education indicators. The results of the study show that international trade leads to contradictory effects. On the one hand, trade openness increases employment opportunities for women. On the other hand, it tends to exacerbate existing inequalities. More recently, Korinek et al. (2021) show the impact of trade on gender inequality from several perspectives. In general, women face higher barriers to entry into global markets and are concentrated in lower value-added sectors. In the specific context of Latin America, the study points to significant barriers for women, such as relatively greater difficulties in accessing credit and more time spent on caregiving. In the case of Mexico, Ben Yahmed and Bombarda (2020) also find multiple effects of trade integration on the gender gap. On the one hand, trade openness favours job creation. On the other hand, it is particularly detrimental to less educated women, who continue to rely heavily on informal employment.

Some of these trends differ from those observed in developed countries. Several papers have also identified a gender gap in sectors integrated into global markets, especially in terms of women's participation and women's wages (Artecona and Cunningham, 2002; Kutlina-Dimitrova et al., 2022; Saure and Zoabi, 2014). However, there are also important differences with respect to Latin American economies. First, because the degree of informality in the labour markets of developed economies is significantly lower. Second, because the gender gap in tertiary education is also smaller. With regard to this second point, it should be clarified that although the number of women enrolled in higher education is similar to that of men in the economies of the global North, there are also significant differences in enrolment in STEM subjects (European Commission, 2022; Evagorou et al., 2024). Based on the previous literature, we can establish the following hypothesis.

H1. Higher integration into foreign markets leads to an increasing gender gap

In this sense, the study of the gender gap must incorporate additional factors to the evolution of the employment level, such as the role played by women in management positions, the evolution of birth rates in the population in conjunction with the gender role associated with women in terms of childcare, the level of access to higher education and, in line with what was commented above and more in relation to labour markets, the role played by women in STEM branches, both in terms of their participation in employment and the evolution of these sectors in the national context and in relation to their insertion in global markets (Haveman and Beresford, 2012; Kräft, 2022).

Promoting STEM activities can play a key role in reducing the gender gap in Latin American labor markets, essentially by designing policies that lead to greater female participation in these areas. To understand the underrepresentation of women in STEM sectors, we must start from family and socio-cultural environments. First, it should be noted that, in the Latin American context, the number of women enrolled in higher education is similar to or higher than the number of men. However, this parity is not reflected in STEM areas (García-Holgado et al., 2020; García-Peñalvo et al., 2022). Second, we must consider the role played by personal preferences when choosing higher education studies, preferences that are deeply determined by gender stereotypes, the sociocultural environment, and the family environment (Wang and Degol, 2017). And, thirdly, we must stop considering biological differences between the sexes as a possible explanatory factor, insofar as the literature shows, by consensus, little evidence along these lines.

Regarding the relationship between STEM fields, gender gaps and global markets, recent studies highlight that while international trade has the potential to drive economic growth and innovation, it can also interact with inequalities, including STEM-related activities. For example, Farokhi (2015) emphasizes the necessity of developing a STEM-based economy in countries with less economic resources to bridge the economic divide and enhance global competitiveness. This is essential for retaining skilled STEM workers and preventing the migration of talent to developed countries. Bruno and Faggini (2021) further elucidate that export-led economies, which benefit from a positive balance of trade, tend to offer more job opportunities, thereby increasing the opportunity cost of higher education and discouraging enrolments in STEM fields due to the higher availability of jobs. Campillay (2024) provides one of the few papers linking STEM, international trade and gender inequality. The paper identifies significant barriers faced by women-led STEM in medium sized enterprises in Chile, including gender biases, work-life balance challenges, and limited access to financing. These barriers hinder the full participation of women in international trade and highlight the importance of gender-sensitive trade policies. However, this relationship, incorporating the gender gap in STEM fields, has not been explored extensively in the literature.

Nontheless, both elements are intertwined based on the analysis of the technological and knowledge intensity of exports. In this sense, several papers point to significant disparities in sex segregation between productive sectors, with different representations between men and women depending on the subset of sectors of activity attending to their technological intensity (Morais Maceira, 2017). However, the role played by these exports, particularly from a value-added perspective, in reducing the gender gap are a scarcely analysed factor (Campos-Romero and Blanco-Varela, 2023), especially in the Latin American context. This may be due to their historical dependence on external technology and their clear extractives productive orientation (Alvarado et al., 2017; Rodil Marzábal and Martín Ruiz, 2021). In this respect, the higher share of industry in economic activity in the case of Mexico compared to Brazil and Chile should be taken into account. With this in mind, we can formulate the second hypothesis of the study.

H2. Higher value-added foreign trade leads to a lower gender gap in STEM employment

In summary, the literature shows that trade liberalisation can increase employment opportunities for women, but can also exacerbate existing inequalities. In Latin America, trade and FDI inflows have created new employment opportunities but increased employment inequalities due to pre-existing gender and educational gaps. Developed countries have lower labour market informality and smaller gender gaps in tertiary education, although significant differences in STEM enrolment persist. Policies that promote women's participation in STEM can help reduce the gender gap in Latin American labour markets.

3. Data and methodology

This section outlines the data and methodologies employed to examine the gender gap in STEM disciplines within Brazil, Chile, and Mexico. The data analysis utilizes quantitative methodologies, including descriptive analysis and regression models. This analytical approach enables the identification of patterns and trends in women's participation in STEM disciplines across these countries, as well as an exploration of the potential causes and factors influencing this participation.

To gather employment-related indicators for Brazil, Chile, and Mexico, specifically to analyse the employment and gender gap within STEM fields, we utilized microdata from national surveys in these countries. These surveys typically assess household living conditions, offering insights into the sector of activity and specific occupations. For Brazil, the *Pesquisa Nacional por Amostra de Domicílios* (PNAD) was utilized. In Chile, the analysis was based on the *Encuesta de Caracterización Socioeconómica* (CASEN), and for Mexico, the *Encuesta Nacional de Ingresos y Gastos de Hogares* (ENIGH) was employed. The PNAD provides annual data, whereas the CASEN and ENIGH conduct surveys biennially, necessitating the imputation of data for certain years. Specifically, for Chile, data were available for the years 2011, 2013, 2015, and 2017[1]; for Mexico, the microdata covered the years 2012, 2014, 2016, and 2018. Regarding data imputation, two criteria were adopted to best approximate the trend of the variables: if data for both the preceding and subsequent years were available, we imputed the average of these two years. If subsequent year data were unavailable, the value from the previous year was adjusted by the average annual rate of change observed in preceding years.

To classify an individual as employed in a STEM field, we rely on the occupation classifications provided by each national survey. The specific occupations deemed as STEM in each country are detailed in Table A1 in Appendix. Furthermore, when available, we utilize the survey weighting factors to ensure that our findings are representative of the broader society.

For analysing the impact of exports, specifically high and medium-high technology exports, and knowledge-intensive services exports, both in terms of DVA[2], we conduct four panel data estimations with the following structure:

$$GAPi = \beta_0 + \beta_1 TEXP_{st} + \beta_2 KIEXP_{st} + \beta_3 DUNCAN_{st} + \beta_4 FR_{st} + \beta_5 PROD_{st} + \varepsilon_{st} \quad (1)$$

Where *GAPi* represents the different gap measures that we propose in each model. *GAPE* quantifies the ratio of female to male employment across the entire economy. *GAPST* considers the gender gap across STEM occupations. *GAPSTM,* and *GAPSTS* specifically measure the gender gap within the manufacturing and services sectors, respectively. *TEXP* represents domestic value-added of high and medium-high in technological intensity goods exports, whereas *KIEXP* denotes domestic value-added knowledge-intensive services exports. *DUNCAN* assesses the Duncan index of the economy, which serves as an indicator of gender segregation within the labour market. *FR* denotes the fertility rate, and *PROD* refers to the productivity of the economy, calculated as the ratio of total output to the number of employed individuals. The Duncan, a metric of gender segregation, is determined as follows:

$$D = \frac{1}{2} \sum_{ij} \left| \frac{F_{ij}}{F} - \frac{M_{ij}}{M} \right|; \quad 0 \le D \le 1 \quad (2)$$

1 Data from Chile for the year 2020 have not been used because it is highly conditioned by the COVID-19 pandemic.
2 See tables A2 and A3 in the Appendix for technology-intensity manufacturing classification and knowledge-intensity services classification respectively.

Where F_{ij} and M_{ij} are female and male employment, respectively, in sector i and occupation j, with F and M being total female and male employment, respectively. This index ranges between 0 and 1, representing the proportion of individuals who would need to change occupations to avoid gender segregation within the labour market. A value closer to 0 indicates minimal or no segregation. Following the Hausman test outcomes, the estimations are conducted using a specification based on a fixed effects model. Finally, Table 1 outlines the descriptive statistics, definitions, and sources for each variable included in the estimation.

Table 1. Descriptive statistics. N. of observations: 240

	Mean	Std. Dev.	Min	Max	Definition	Source
GAPE	0.7	0.03	0.64	0.75	Female to male employment for the total economy, STEM occupations, and STEM occupations in manu-facturing and services	Own elaboration from *PNAD* (Brazil), *CASEN* (Chile), and *ENIGH* (Mexico)
GAPST	0.6	0.17	0.29	0.8		
GAPSTM	0.21	0.05	0.09	0.29		
GAPSTS	0.8	0.23	0.37	1.05		
DUNCAN	0.58	0.07	0.49	0.73	Duncan index in STEM employment	
TEXP	37.98	23.03	12.11	69.59	High and medium-high DVA exports as a share of total industry DVA exported (%)	Own elaboration from *TiVA,* OECD (2023 edition)
KIEXP	17.77	10.06	3.96	30.92	Knowledge intensive services DVA exports as a share of total services DVA exported (%)	
PROD	337522.1	420592.1	23513.45	987021.2	Total output to total employment ratio	Own elaboration from *TiVA* (OECD, 2023 edition), and The World Bank
FR	1.85	0.22	1.55	2.29	Fertility rate (%)	The World Bank

Source: Authors from PNAD, CASEN, ENIGH, TiVA (OECD, 2023 edition), and The World Bank.

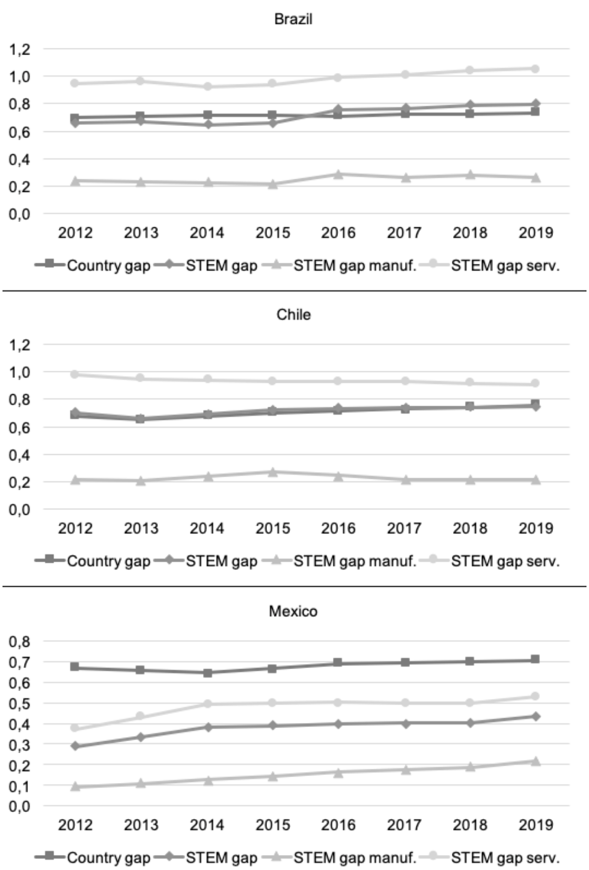
4. Results and discussion

4.1. Descriptive analysis

This section presents a descriptive analysis of gender gaps, value-added exports, and gender labour segregation within Brazil, Mexico, and Chile. Accordingly, Figure 1 depicts the gender gap, represented by the ratio of women to men, across four dimensions: the country gap, the STEM fields gap, and the STEM fields gap within the manufacturing and services sectors.

In Brazil and Chile, the overall STEM disciplines gender gap mirrors the general country gap throughout the analysed period. Conversely, Mexico exhibits a different scenario, where the gender gap in STEM fields is twice the size of the overall country gap. Apart from construction, in all three countries, the most significant gender gap is found in the proportion of women employed in the manufacturing sector. This discrepancy is mitigated by a higher representation of women in STEM-related jobs within the service sector in Brazil and Chile, with the former even showing an increased proportion of women from 2017 to 2019. Mexico, however, presents a different pattern, with a larger gender gap in services compared to the economy at large. The general trend over the period indicates a gradual narrowing of these gaps, with the smallest gap seen in STEM services. Nevertheless, the three countries analysed exhibit a persistent and widespread gender gap, the effects of which are reduced among service activities.

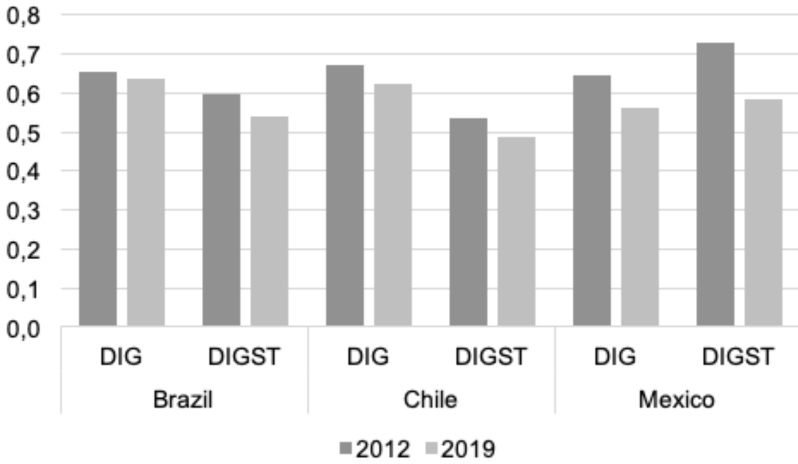
Figure 1. Gender gap in Brazil, Chile, and Mexico, 2012-2019



Source: Authors from PNAD, ENIGH, and ECSN.

Figure 2 represent the degree of sex segregation, as quantified by Duncan's index (see Expression (2)), across Brazil, Chile, and Mexico. The trend in segregation is analysed by considering the entire economy as well as specifically within STEM activities, for the years 2012 and 2019. The findings indicate that segregation was more pronounced in 2012 compared to 2019. In Brazil and Chile, segregation levels are observed to be higher across the entire economy than within STEM disciplines. This pattern does not hold in Mexico, where the STEM fields, particularly those that are most innovative, exhibit greater levels of segregation.

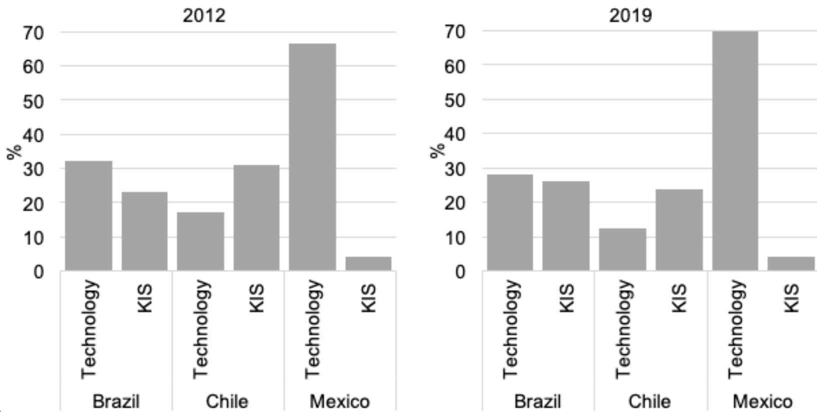
Figure 2. Duncan index for total employment (DIG), and for STEM employment (DIGST)



Source: Authors from PNAD, ENIGH, and ECSN.

To conclude the descriptive analysis, Figure 3 illustrates the proportion of high and medium-high technology exports within total manufacturing exports, as well as the share of knowledge-intensive services exports within total services exports, all measured in terms of DVA. Throughout the observed period, the export profiles of these countries exhibit no significant changes. Notably, the technological profile of manufacturing exports from Brazil and Chile is low, whereas in Mexico, such exports constitute approximately 70% of total DVA exports. This discrepancy can be attributed to Mexico's deeper integration into the North American value chain, particularly within the automotive sector. In terms of services, none of the three countries demonstrate significant exports in knowledge-intensive services, with Mexico especially lagging, where these account for barely 4% of the total.

Figure 3. Share of high and medium-high DVA exports to total industry DVA exported (technology) and share of intensive services DVA exports to total services DVA exported (KIS)



Source: Authors from TiVA (OECD, 2023 edition).

These findings underscore the limited encouragement for higher value-generating tasks in these countries, which, except for Mexico, continue to show extractivist tendencies in their approach to foreign trade integration. This situation could impede the advancement of more STEM-related activities. The following subsection presents the results of the estimates presented in Expression (1).

4.2. Econometric results

This subsection shows the primary outcomes of the four panel data estimations for Brazil, Chile, and Mexico. Based on the findings of the Hausman test, we follow a fixed-effect estimation strategy (see Table 3). These results offer a nuanced view of the employment gender gap, both in general terms across the entire economy (GAPE) and within STEM disciplines (GAPST). Further, this gap is decomposed into two distinct components: the gap in manufacturing STEM disciplines (GAPSTM) and the gap in services (GAPSTS), which represent the more innovative sectors of the economy. This differentiation is useful and necessary because of the multidimensional nature with which the gender gap must be addressed. (Morales Inga and Morales Tristán, 2020).

Regarding GAPE, the analysis reveals that TEXP exerts a significant negative impact, suggesting that an increase in technology-intensive exports could result in a higher gender gap within the economy. This outcome is attributed to the pronounced gender segregation across various sectors, notably due to the diminished participation of women in manufacturing activities. Consequently, an increase in industrial activity, driven by a surge in manufacturing exports, would, all else being equal, lead to a comparatively greater rise in male employment. Furthermore, the fertility rate demonstrates a significant negative effect, indicating that higher fertility levels may intensify the employment gender gap. This could be attributed to the societal roles of women, especially regarding household and caregiving responsibilities (Berniell et al., 2021, 2023). The results of this model lead us to verify *H1*, although this result can and should be qualified depending on the sectors and occupations considered, as well as the trade flow, as shown below.

In relation to GAPST, the results show that KEXP has a statistically significant impact in reducing the gender gap. Conversely, TEXP and DUNCAN exhibit negative effects, suggesting that exports of higher technological value and gender segregation in the labour market substantially contribute to the gender gap within STEM fields. Consequently, the sexual division of labour acts as an impediment to women's entry into STEM occupations, and the exports of high- and medium-high-technology have a detrimental effect on enhancing women's participation in these sectors (Lara-Prieto et al., 2023). This leads to diminished economic opportunities for women in terms of straightforward labour market involvement compared to men.

In the GAPSTM model, which specifically examines the gender gap in STEM manufacturing activities, the variables that exert the most significant impact on female labour participation are DUNCAN and FR, exhibiting positive and negative coefficients, respectively. This finding suggests that occupational segregation hinders women's access to employment opportunities in STEM manufacturing fields. Conversely, a higher fertility rate is correlated with increased job entry rates for women in these sectors.

The divergent impacts of fertility on GAPE (which exacerbates the gender gap in overall employment) and GAPSTM (where it is associated with a reduction in the gender gap within STEM fields) can be explained by examining the interplay of socio-economic, cultural, and labour policy contexts. On the one hand, the negative effect on GAPE might stem from the traditionally higher caregiving responsibilities associated with a higher fertility rate, which could restrict women's participation in the labour market. In this analysis, the entire female labour market is considered, encompassing jobs across various education levels and sectors, thus reflecting the full spectrum of the economy and labour market policies that may disproportionately disadvantage women. This situation is exacerbated by the absence of supportive family and maternity policies, such as paid parental leave, affordable childcare access, and financial constraints in covering these costs.

On the other hand, the GAPSTM model suggests that the labour market environment within STEM fields may offer more favourable conditions that positively impact women with children. These conditions could include more stable working hours, specific job benefits, or a work culture more inclusive of working mothers. Such factors potentially mitigate the negative effects of higher fertility on women's employment in STEM manufacturing disciplines, highlighting the significance of job quality and supportive labour policies in narrowing the gender gap in this sector (Arora et al., 2021). To some degree, this outcome could also be associated with women who have more children opting to seek employment, possibly facilitated by extended family support networks or shifts in family structures, as established by Esteve et al. (2022).

The fourth model, which examines the gender gap in STEM services, shows that KEXP has a significant positive effect. This finding suggests that knowledge-intensive exports have the potential to diminish the gender gap in the services sector. However, this effect should not be considered in isolation but rather in conjunction with the GAPSTM model, where manufacturing exports exhibit an opposite impact, as also shown by Arora et al. (2023). While a deep and enduring gap exists in manufacturing, the services sector –particularly in Brazil and Chile– exhibits a scenario closer to gender parity. Consequently, an increase in exports of services could lead to a rise in female employment, mirroring the effect on male employment. Collectively, the findings from the GAPSTM and GAPSTS models underscore the enduring nature of gender roles and illustrate how services, both within STEM fields and more broadly, remain predominantly feminized sectors.

Generally, productivity within the economy does not emerge as a significant factor in advancing gender equality. This observation suggests that within the context of the countries analysed, socio-cultural factors exert a more substantial influence on the gender gap, as well a lack of proper policies to mitigate it. However, the potential impact of increased female participation in the productive structure on enhancing GDP should not be underestimated (Tejada et al., 2021). Table 2 summarises the results of the econometric analysis. Combined, the results of the GAPST, GAPSTM and GAPSTS models do not allow us to categorically confirm or reject *H2*. The gender segregation of economic activities plays an important role in the impact of foreign trade flows on the gender gap. In the case of manufacturing, where male employment predominates, an increase in high and medium-high technology exports would widen the gap, while the opposite is true for knowledge-intensive services exports, where female employment is more prominent.

In conclusion, the findings of this study lead to several policy recommendations aimed at closing the gender gap in STEM and the broader labour market. First, there is a need for enhanced focus on gender-neutral education policies to tackle early gender segregation in STEM disciplines (Cuberes et al., 2022; Tacsir et al., 2014; Verdugo-Castro et al., 2021). Second, the development of public policies that enable women to share childcare and household responsibilities more equally with their male counterparts is crucial. Such policies should aim to facilitate a better work-life balance and promote equal caregiving roles among parents (Bustelo et al., 2019; Jergins, 2023). Third, in light of the significant role played by technology- and knowledge-intensive exports, economic and industrial policies should be crafted to encourage a shift towards higher value-added activities. This transition should be supported by strategies to increase female participation in manufacturing sectors, thereby amplifying the positive outcomes of this shift in the productive landscape. Additionally, in the services sector, efforts should be made to enhance women's involvement in activities that have a more technical and technological focus, while also addressing the need for greater gender equity in sectors predominantly staffed by women, such as healthcare and education within STEM disciplines, as also pointed out by Sáinz (2020) and de García Ucero (2023).

Table 2. Estimation results summary

Model	Comment
GAPE (gender gap in total economy)	High- and medium-high technology exports may increase the gender gap. No significant effect is found for knowledge-intensive exports and sectoral composition.
GAPST (gender gap in STEM occupations)	High- and medium-high-technology exports may widen the gender gap in STEM occupations, while knowledge-intensive exports may help to narrow it. The gender segregation that already exists across sectors tends to perpetuate this gender gap in employment.
GAPSTM (gender gap in manufacturing STEM occupations)	Manufacturing sectors show the largest gender gaps, including those where STEM occupations are abundant. Gender segregation in economic activities tends to feed back into the existing gap.
GAPSTS (gender gap in services STEM occupations)	Knowledge-intensive exports can lead to a narrowing of the gender gap. This is particularly due to the increased presence of women in services, including those where STEM occupations are abundant.

Table 3. Panel data estimation results

	GAPE		GAPST		GAPSTM		GAPSTS	
	Coefficient (Standard error)	t-value	Coefficient (Standard error)	t-value	Coefficient (Standard error)	t-value	Coefficient (Standard error)	t-value
TEXP	-0.00464 (0.0015)	-3.15***	-0.00639 (0.0035)	-1.83*	0.00289 (0.0021)	1.35	-	
KEXP	-0.00128 (0.0016)	-0.79	0.0083 (0.0039)	2.15*	-	0.01489 (0.0032)	4.63***	
DUNCAN	-0.17450 (0.1767)	-0.99	-1.25403 (0.419)	-2.99***	-1.09752 (0.2481)	-4.42***	-0.51833 (0.3719)	-1.39
FR	-0.13009 (0.0658)	-1.98*	-0.00895 (0.1561)	-0.06	0.15443 (0.083)	1.86*	-0.10808 (0.1386)	-0.78
PROD	-2.84E-8 (1.09E-7)	-0.26	2.99E-7 (2.59E-7)	1.16	1.79E-7 (1.69E-7)	1.06	3.82E-8 (2.26E-07)	0.17
CONSTANT	1.24947 (0.0709)	17.62	1.33725 (0.1681)	7.95	0.38633 (0.106)	3.64	1.01795 (0.0981)	10.38
R^2 within	0.85		0.78		0.76		0.76	
R^2 between	0.76		0.83		0.93		0.95	
R^2 overall	0.37		0.83		0.43		0.94	
rho	0.99		0.92		0.99		0.92	

Source: Authors from PNAD, CASEN, ENIGH, TiVA (OECD, 2023 edition), and The World Bank
Note: "***", "**", and "*" represent significance level at 1%, 5%, and 10% respectively.

5. Conclusions

The underrepresentation of women in STEM fields is a persistent and concerning issue. This gender gap not only hinders economic development and the transition towards high-tech and innovative industries and knowledge-intensive services, but it also leads to an inefficient allocation of labour and human capital potential. Despite the efforts to increase the number of women in STEM fields, there are still significant disparities (Diekman et al., 2010). One plausible explanation for these disparities in the Latin American context lies in the social roles ascribed to women, which are influenced by their educational expectations. However, the reasons behind these gender disparities in STEM are multi-faceted and require further examination. To address the gender gap in STEM disciplines and promote female participation in these fields, it is important to understand the underlying factors contributing to this disparity.

Several studies have suggested various factors that contribute to the gender gap in STEM disciplines. These factors include social and cultural norms, stereotyping, lack of female role models, unconscious bias in education and hiring processes, limited access to resources and opportunities, and negative experiences and treatment of women in STEM fields. While many studies have explored the relationship between career choices and gender stereotypes, particularly in the context of STEM, there remains a significant gap in research examining STEM's performance in the labour market. Similarly, the impact of foreign trade, especially in relation to activities associated with higher levels of technology and innovation, has not been thoroughly investigated. This paper contributes valuable insights into how economic opportunities might influence women's participation in STEM disciplines. We have examined occupational segregation and the gender gap considering the effects of foreign trade by analysing the impact of high-technology and service DVA exports.

As Latin America progresses towards a future shaped by innovation and technology, understanding the status of women in STEM disciplines in countries like Brazil, Chile, and Mexico becomes imperative. Such an analysis can not only illustrate the challenges women face in these fields but also provide critical insights for the development of policies and programs aimed at encouraging women's participation in science and technology. The findings of this research underscore a significant and enduring gender gap, especially in women's involvement in high-technology manufacturing activities. They also highlight the crucial role of external economic engagement and the export of high value-added products and services. However, while the results show that foreign trade does have an impact on the gender gap, both in the economy in general and in STEM activities in particular, this impact is determined by the pre-existing gender segregation in the labour market between different sectors of activity.. This underscores the significance of the production and labour structure in creating new opportunities for high quality and equal employment.

In conclusion, the findings of this study lead to several policy recommendations aimed at closing the gender gap in STEM and the broader labour market. First, there is a need for enhanced focus on gender-neutral education policies to tackle early gender segregation in STEM disciplines (Cuberes et al., 2022; Tacsir et al., 2014; Verdugo-Castro et al., 2021). Second, the development of public policies that enable women to share childcare and household responsibilities more equally with their male counterparts is crucial.

Such policies should aim to facilitate a better work-life balance and promote equal caregiving roles among parents (Bustelo et al., 2019; Jergins, 2023). Third, in light of the significant role played by technology- and knowledge-intensive exports, economic and industrial policies should be crafted to encourage a shift towards higher value-added activities. This transition should be supported by strategies to increase female participation in manufacturing sectors, thereby amplifying the positive outcomes of this shift in the productive landscape. Additionally, in the services sector, efforts should be made to enhance women's involvement in activities that have a more technical and technological focus, while also addressing the need for greater gender equity in sectors predominantly staffed by women, such as healthcare and education within STEM disciplines, as also pointed out by Sáinz (2020) and de García Ucero (2023).

This study acknowledges two limitations. First, it does not delve into the working conditions of women in labour markets, suggesting that gaps in representation may not fully encapsulate the breadth of disparities present. Additionally, national surveys examining work structure and living conditions occasionally lack consistency across different editions, necessitating some results to be estimated to maintain statistical validity.

Addressing the first limitation, a future research line involves a thorough analysis of women's participation in STEM, focusing on employment quality, contract types, and wage levels. This approach aims to provide a deeper understanding of the working conditions women face in STEM fields. Another valuable line of research would be to examine in greater detail the impact of foreign trade on the gender gap, with a particular emphasis on the roles played by different sectors of activity. Additionally, a detailed investigation of the most innovative and leading STEM jobs leading sectors within Latin American economies could offer insights necessary for crafting a suite of public policies. These policies would not only aim to foster economic growth but also to advance gender equality, thereby addressing both the economic and social dimensions of the gender gap in STEM.

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Appendix

Table A1. STEM occupations

High management positions	Dieticians and nutritionists
Finance-management position	Speech therapists and logopaedists
Physicists and astronomers	Optometrists
Meteorologists	Health professionals not previously classified
Chemists	University and higher education teachers
Geologists and geophysicists	Vocational training teachers
Mathematicians, actuaries, and statisticians	Secondary school teachers
Biologists, botanists, zoologists, and the like	Information technology instructors
Agronomists and related professionals	Financial analysts
Environmental protection professionals	Systems analysts
Engineers	Programme and application developers (software)
Architects	Web and multimedia developers
Urban planners and traffic engineers	Application programmers
Cartographers and surveyors	Developers and analysts of programmes and applications (software) and multimedia not previously classified
Graphic and multimedia designers	Database designers and administrators
Doctors	Systems administrators
Nursing professionals	Computer network professionals
Childbirth professionals	Database and computer network specialists not previously classified
Traditional and alternative medicine practitioners	Economists
Paramedics	Psychologists
Veterinary surgeons	Physical and chemical science technicians
Dentists	Civil engineering technicians
Pharmacists	Electrotechnicians
Occupational and environmental health and hygiene professionals	Technicians
Physiotherapists	

Source: Authors from PNAD.
Note: We have selected the equivalent occupations in Mexico and Chile.

Table A2. High technology of manufacturing industries classification

High-technology
Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacture of computer, electronic and optical products
Medium-high technology
Manufacture of chemicals and chemical products
Manufacture of electrical equipment
Manufacture of machineryand equipment n.e.c.
Manufacture of motor vehicles, trailers and semi-trailers
Manufacture of other transport equipment
Medium-low-technology
Manufacture of coke and refined petroleum products
Manufacture of rubber and plastic products
Manufacture of other non-metallic mineral products
Manufacture of basic metals
Manufacture of fabricated metal products, except machinery and equipment
Repair and installation of machinery and equipment
Low-technology
Manufacture of food products
Manufacture of beverages
Manufacture of tobacco products
Manufacture of textiles
Manufacture of wearing apparel
Manufacture of leather and related products
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Manufacture of paper and paper products
Printing and reproduction of recorded media
Manufacture of furniture
Other manufacturing

Source: Authors from Eurostat.

Table A3. Knowledge intensive services classification

High-tech knowledge-intensive services
Motion picture, video and television programme production, sound recording and music publishing activities
Programming and broadcasting activities
Telecommunications
Computer programming, consultancy and related activities
Information service activities
Scientific research and development
Knowledge-intensive market services (excluding financial intermediation and high-tech services
Water transport
Air transport
Legal and accounting activities
Activities of head offices; management consultancy activities
Architectural and engineering activities; technical testing and analysis
Advertising and market research
Other professional, scientific and technical activities
Employment activities
Security and investigation activities
Knowledge-intensive financial services
Financial service activities, except insurance and pension funding
Insurance, reinsurance and pension funding, except compulsory social security
Activities auxiliary to financial services and insurance activities
Other knowledge-intensive services
Publishing activities
Veterinary activities
Public administration and defence; compulsory social security
Education
Human health activities
Residential care activities
Social work activities without accommodation
Creative, arts and entertainment activities
Libraries, archives, museums and other cultural activities
Gambling and betting activities
Sports activities and amusement and recreation activities

Source: Authors from Eurostat.