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Abstract

We provide evidence on the direct and indirect effects of trade and infrastructure on women's participation in the labor force. We use panel data from 91 developing and emerging economies, and examine the impacts of openness to international trade and three indicators of infrastructure (access to electricity, mobile phone subscriptions and internet use) on female labor force participation. Fixed-effects and instrumental variable fixed-effects estimates suggest that both trade and access to electricity have non-linear (U-shape) effects on female labor force participation, and have additional region-specific impacts which are negative in the case of the Middle East and North Africa, and positive in the case of Latin America and the Caribbean, but do not seem to have additional effects from interactions with each other. On the other hand, we find that mobile phone and internet use boost women's labor force participation through their interplay with trade. We discuss the policy implications of these findings.

Keywords: international trade, infrastructure, electricity use, internet use, mobile phones, ICT, female labor force participation
JEL classification: F16, J21, O1

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I. Introduction

Over the last three decades, many developing countries have liberalized trade and increased the share of manufacturing and service sectors in total output. Most developing economies have also improved health and education levels, with some countries experiencing remarkable improvements during the last 25 years or so. Notably, female health outcomes and educational attainments have improved in many parts of the world, including in low and lower-middle income countries. Yet, in some regions, women's labor force participation remains persistently low (Figures 1a, 1b, and 2), compared with the participation rates of their male counterparts.

Figure 1a shows that over the course of four decades (1990-2018), regions with the lowest female labor force participation—Middle East and North Africa ((MENA) and South Asia Pacific (the latter experienced a decline in female labor force participation in the last two decades)—have not managed to close the gap with regions where female labor force participation is high: Latin America and the Caribbean (LAC), sub-Saharan Africa (SSA) and East Asia and the Pacific (EAP). On the other hand, female labor force participation has increased in the last four decades from 44.3% in 1990 to 54.3% in 2018 in LAC and has remained stable in SSA, at a rate exceeding 63%, while women's participation in the labor force in EAP has decreased, from 74.3% in 1990 to 66.1% in 2018.

Figure 1b shows that men's participation in the labor force exceeds 70% in South Asia and MENA countries, compared to rates lower than 22% and 30%, respectively, for women. This extreme gender inequality in the labor force in these two regions is clearly portrayed in Figure 2, where the female share of the total labor force in 2018 is 20% and 23% in MENA and South Asia, respectively. These rates suggest that for every five participants in the labor force in the MENA region four are male and only one is a female, while in South Asia women, on average, represent less than one-fourth of the labor force.

Numerous studies have considered social attitudes, laws (e.g., land tenure and family law), and fertility to be key drivers behind the problem of 'missing women in labor markets'. On the other hand, many studies, especially in the field of economics, have argued that certain economic policies, or at least their outcomes, may have had gendered effects that are biased against women. Notably, export promotion and trade liberalization seem to be prominent in empirical studies focused on identifying factors that influence gender gaps in wage, employment, and labor force participation (Berik *et al*, 2004; Gaddis and Pieters, 2017; Juhn *et al*, 2014; Pieters, 2018; Baliamoune-Lutz, 2020 and 2021; Kyander, 2020).

The literature has also investigated the influence of infrastructure on female labor force participation and employment by examining the effects of transportation (Kim, 2019; Lei *et al*, 2019; Martinez *et al*, 2020), electrification and access to electricity (Dinkelman, 2011; Grogan and Sadanand, 2013; Rathi and Vermaak, 2018; Trenezakis and Tritah, 2020; Chhay and Yamazaki, 2021; Sedai *et al*, 2021), and information communication technologies (Dettling, 2017; Nkoumou Ngoa and Song, 2021; Bahia *et al*, 2021; Kusumawardhani *et al*, 2021).

While both trade and infrastructure have, separately, been shown to influence women's participation in labor markets, work on the impacts of the interactions between trade and infrastructure on female labor market outcomes in developing countries is remarkably scant. To the best of our knowledge, the present paper is the first work to address the question of whether the interplay of trade and infrastructure exerts an influence on female labor participation in developing countries, using macro-level data. Thus, by exploring the impact of the interplay of three indicators of infrastructure (access to electricity, mobile phone and internet use) with openness to international trade, we aim to fill this gap and make a novel contribution to the empirical literature.

From the standpoint of women's supply of labor, the question of whether interactions between international trade and infrastructure affects women's participation in the labor force (beyond the independent effects trade and infrastructure may have) is interesting for at least three reasons. First, when infrastructure is poor, women may not be able to travel to the workplace even if there is no gender discrimination in employment, for example as a result of increasing international trade (Becker, 1971), and may not join the labor force. When the quality of transportation infrastructure is poor, both increasing competition from imports and greater opportunities for exports may cause women to leave the labor force. Import-competing firms may be forced to relocate to farther and cheaper locations within the country to be able to compete against foreign producers (imported goods), while firms in the export sector may be lured to other locations to take advantage of agglomeration and other benefits in those locations (e.g., export zones). In both situations, some women would find it more costly or unsafe to travel to these new locations for work and, consequently, may withdraw from the labor force.

Second, better quality and more available infrastructure increases women's time allocation to market (productive) activities (Agénor and Canuto, 2014). Electrification and home appliances for example, can free women from full-time household drudgery and enable them to participate in the labor force (Greenwood, 2019), so that women are able to benefit from trade-induced employment. However, when such infrastructure is poor or lacking, women will not be able to allocate more time to non-home (market) activities, in which case increased openness to trade would have only negligible effects on female labor force participation.

Third, infrastructure can remove distance between home and the workplace. This is especially the case with the advent and diffusion of information and communication technologies (ICTs). ICT use (especially internet use) have facilitated working from home (telework, distance working, or at-home workers), shopping from home, training from home, and other activities that, prior to the advent of the internet, required significantly more time and mobility to undertake. An important added benefit of ICT for women is that activities undertaken from home and the ability to acquire information instantly also remove personal security concerns. Thus, when a country increases its openness to international trade, and in the presence of developed and widely diffused ICTs, we should expect an increase in female labor force participation.

Additionally, many studies have examined links between infrastructure and international trade (Nordås and Piermartini, 2004; Donaubauer *et al*, 2018; Donaldson, 2018; Trew, 2020) and generally concluded that infrastructure influences a country's trade performance. Therefore, accounting for the role of the interaction between trade and infrastructure should improve estimates of the effects of trade on labor force participation. It is also worth noting that both trade and infrastructure can also affect the male labor force and, depending on the relative impacts (male compared with female labor supply), the interplay of infrastructure with trade openness could exert different influences on male and female labor forces. Thus, an empirical investigation of the impacts on *women's* participation in the workforce is warranted.

The econometric results obtained in this paper indicate that trade and access to electricity (an indicator of physical infrastructure), as well as interactions between trade and two indicators of ICT infrastructure, have positive impacts on women's labor force participation. However, the impacts of trade and access to electricity are nonlinear; they become positive only beyond a high threshold level. We also found region-specific effects of openness to international trade, which are positive in the case of Latin America and the LAC and negative in the case of MENA.

The remainder of the paper is organized as follows. Section 2 provides an overview of relevant literature. In Section 3, we describe the variables and methodology we use in the empirical analysis and present the estimation results. Section 4 summarizes the findings and concludes.

II. Overview of Related Literature

This paper aims to contribute additional insights to three strands of literature: (i) studies examining the influence of trade on female labor force participation and employment, (ii) research on the effects of infrastructure on women's participation in labor markets, and (iii) the literature on the links between infrastructure and openness to trade. As noted above, this paper makes a new contribution by combining insights from these three strands of literature and exploring the effects of trade, infrastructure, and their interactions on women's participation in the labor force.

2.1. Trade and women's participation in labor markets

There is a vast literature on the effects of international trade on women's labor force participation, wages, employment, and gender gaps in labor markets. The theoretical literature generally predicts a negative link between trade and gender gaps, that is, greater openness to international trade, which would expose domestic firms (particularly in concentrated industries) to higher levels of competition, should reduce gender gaps in employment. Most of this literature confirms Becker's prediction that trade-induced increases in competition would increase the cost of discrimination (Becker, 1971) and, thus, would reduce wage and employment gender gaps. On the other hand, more recent theoretical studies differentiated between skills and concluded that the female labor force participation could fall, and the gender wage gap may widen (Sauré and Zoabe, 2014) as a result of trade liberalization. Even when greater openness to trade enables women to increase employment, gender gaps in wages may persist, as women could be predominantly employed in low-skill and low-paying occupations (Juhn *et al*, 2014).

Empirical studies have reported mixed evidence[1]. Most of the empirical work uses micro-level data from a specific country or very limited number of countries and industries. As noted in Baliamoune-Lutz (2020), evidence from a large body of work using micro-level (industry) data suggests that there are "*either negative impacts of increased openness to trade on women's participation in the labor force and in wage employment, or a positive impact that is associated with women being over-represented in low-wage occupations*."

Using data from 92 developed and developing economies, Busse and Spielman (2006) investigated the relationship between trade in labor-intensive manufactured goods and gender inequality and found a positive association between gender wage inequality and comparative advantage in labor-intensive goods, suggesting that countries which export more labor-intensive goods have higher gender wage inequality. Additionally, the authors found that gender inequality in labor market participation was associated with a stronger comparative advantage in labor-intensive goods. These results are consistent with findings in studies on growth, exports, and gender inequality (Seguino 1997, 2000; Baliamoune-Lutz, 2007; Baliamoune-Lutz and McGillivray 2015).

Al Azzawi (2014) examined the impact of trade reforms on women's labor market outcomes in the Egyptian manufacturing sector and found that in industries that were initially competitive, greater import competition was associated with lower female employment and a larger gender wage gap, while greater export intensity was associated with lower female employment and a smaller gender wage gap. On the other hand, in initially concentrated industries, increased export intensity was associated with increased female employment, while greater import competition was associated with a smaller gender wage gap and higher female employment. In contrast, in an earlier study, Berik *et al*, (2004) found that competition from foreign trade in concentrated industries in South Korea and Taiwan was positively associated with wage discrimination against women.

On the other hand, Chen *et al* (2013) reported that export orientation and foreign participation, within the same industry and region in China had a positive effect on female employment. However, Baliamoune-Lutz (2020) used macro-level data from a large group of developing and emerging economies and found that openness to trade affected different regions differently. While trade increased the female share of wage employment in most regions, it had a negative impact in North Africa. Interestingly, Baliamoune-Lutz (2021) found that export sophistication had a positive impact on the share of women in wage employment, including in North Africa, but the impacts were positive only at high levels of export sophistication.

Based on data from Mexico for the period 1993-2001, Ben Yahmed and Bombarda (2020) found that reductions in tariffs raised the probability of working formally for men and women within four-digit manufacturing industries. The authors constructed a regional tariff measure and found that "*regional exposure to import liberalization increases the probability of working formally in the manufacturing sector for both men and women, and especially for men*." On the other hand, the authors found that the probability of working formally in the service sectors decreased for low-skilled women. Benguria and Ederington (2017) found that trade increased women's share of higher-paying occupations and

1. There is an extensive empirical literature on the effects of trade and globalization on gender gaps in wage and employment in developed countries, while work using data from developing countries is less extensive but growing. Relatively more recent studies focusing on developing countries include: Ozler (2000), Berik *et al* (2004), Menon and Rogers (2009), Chen *et al* (2013), Aguayo-Tellez *et al* (2014), Guicheney (2015), Benguria and Ederington (2017), Gaddis and Pieters (2017), Baliamoune-Lutz (2020, 2021), Ben Yahmed and Bombarda (2020), and Liao and Paweenawat (2020). Aguayo-Tellez (2011), Gaddis and Peters (2012), and Papyrakis *et al* (2012) provide excellent literature reviews.

increased the returns to primarily female occupations in Brazil, while Gaddis and Pieters (2017) did not find any evidence that women's employment and participation increased relative to men's, or that the pro-competitive effects of trade benefited women.

2.2. Infrastructure and female labor market outcomes

Many studies have investigated the role of public infrastructure as a productive input (Aschauer, 1989; Barro, 1990; Shah, 1992; Dalenberg and Partridge, 1997; Bernstein and Mamuneas, 2008; Calderón *et al*, 2015). Some studies have also focused on the impact of public infrastructure on employment. For example, Dalenberg and Partridge (1997) investigated the roles of public infrastructure (highways) as a productive input and as a household amenity. The authors found that for the manufacturing sector, the productivity impact of highways dominated, but for the economy (as a whole) highways played a stronger role as a household amenity that increased labor supply.

More recent empirical studies have documented the important influence of transportation on female labor force participation in developing and emerging economies. For example, Lei *et al* (2019) used data from the India Human Development Survey and explored the impacts village transportation infrastructure had on female and male agricultural and non-agricultural employment. The authors found that "*access by paved or unpaved roads and frequent bus services increase the odds of non-agricultural employment among both males and females*", but they also found the effect of road access on non-farm employment (relative to not-working) to be stronger for women. On the other hand, using monthly economically active population surveys and the difference-in-difference estimator, Kim (2019) examined the impacts of subways on the women's participation in the labor force in Daejeon, South Korea, and found that female labor force participation rates and employment growth increased significantly, with women aged 50–59 showing the largest subway employment effect, while the effects on men were smaller. Similarly, Martinez *et al* (2020) investigated the impacts of improved urban transport systems on female employment outcomes in Lima, Peru and found that investments in bus rapid transit and elevated light rail were associated with substantial gains in employment and earnings per hour for women, but not for men. The authors concluded: "*these findings suggest that infrastructure investments that make it faster and safer for women to use public transport can generate important labor market impacts for women who reside in the area of influence of the improved infrastructure*."

However, due to lack of reliable macro-level panel data on public transportation infrastructure, the empirical analysis in this paper will focus primarily on three indicators of infrastructure: access to electricity (indicator of electrification infrastructure), mobile phone, and internet use, with the last two variables representing the level of ICT infrastructure.

2.2.1. Electricity and female labor market outcomes

Electrification enabled the adoption of time-saving appliances which, in turn, released women from housework and triggered the steady rise in the United States' female labor supply in the twentieth century (Greenwood *et al*, 2005). Studies using micro-level data from developing countries have found positive effects from electrification on employment (of both men and women) and children's education. For example, using data from Nigeria, Tagliapietra *et al* (2020) explored the effect of electricity access on labor market outcomes. The authors identified a consistent shift of approximately

7% out of agricultural employment and around 15% into non-agricultural employment and found evidence of a positive impact of access to electricity on labor force participation. On the other hand, based on data on a 10% micro sample from the Ghana census, Akpandjar and Kitchens (2017) studied the relationship between electrification and the structures of employment and households using the rollout of electricity in Ghana between 2000 and 2010. The authors found that access to residential electricity caused a movement towards higher skilled wage-earning occupations and out of agriculture, while within the household, access to electricity decreased fertility and increased investment in children's education.

Dinkelman (2011) examined the impacts of rural electrification (mass roll-out of electricity to rural households) on employment in South Africa using an instrumental variable strategy and a fixed-effects approach. She found that electrification had a significant positive impact on female employment within five years. The author argued that "[s]*everal pieces of evidence suggest that household electrification raises employment by releasing women from home production and enabling microenterprises*." However, the author also noted that the mass roll-out of electrification to rural households appeared to raise work hours for both female and male workers, while raising men's earnings and reducing women's wages. Rathi and Vermaak (2018) examined the impact of rural household electrification on labor market outcomes in India and South Africa and found that electrification increased the annual incomes for both men and women (in both countries) working in paid employment. However, while electrification was associated with a reduction in working hours (higher productivity) in India for both men and women, there was no employment benefit from electrification in South Africa. On the other hand, Tenezakis and Tritah (2020) used microeconomic data from Rwanda to assess the impact of the electrification of rural areas on employment and education and found that households connected to electricity allocated, on average, three hours less per week to household chores compared with non-connected households. The authors further noted: "*it appears that in connected households, women participate more in the labor market and when they participate, they work more hours (17 additional hours per week)*."

Research using data from Latin American countries also found evidence of a positive effect of access to electricity on women's participation in labor markets. For example, Grogan and Sadanand (2013) found a strong positive association between rural electrification and men's and women's time use in Nicaragua, even when labor-saving appliances were not available. The authors showed that electricity raised the female propensity to work outside the home by 23%, while it had no impact on male employment. Similarly, Dasso and Fernandez (2015) found that a rural electrification program in Peru increased hours of work and reduced the likelihood of having a second job for men, while it increased employment and earnings and raised the probability of working in the non-agricultural sector for women.

Studies using data from Asian countries have reported similar results. For example, Chhay and Yamazaki (2021) found that access to electricity in Cambodia raised the probability of non-agricultural female and male self-employment by 10-to-11 percentage points over a decade. Using a large gender-disaggregated data set from India, Sedai *et al* (2021) also found that reliable electrification increased female employment opportunity and reduced time allocation to home production. Their results showed that an additional 10 hours of electricity increased the likelihood of employment by 4.2 percentage points for women and 2.8 percentage points for men, implying that the benefits for women were significantly greater.

2.2.2. ICT and women's participation in labor markets

A large body of literature has shown that ICT plays a major role in growth and development in developed and developing countries (Röller and Waverman, 2001; Baliamoune-Lutz, 2003; Cecchini and Scott, 2003; Bollou and Ngwenyama, 2008; Czernich *et al*, 2011; Stanley *et al*, 2018). More recently, several studies have examined the impact of mobile phones and internet use on labor market outcomes, particularly on female labor force participation (Dettling, 2017; Efobi *et al*, 2018; Bahia *et al*, 2021; Ritika, 2021). For example, Dettling (2017) found that use of high-speed home internet increased married women's labor participation rate in the U.S. by 4.1 percentage points, while it had no effects on men or single women. Similarly, empirical evidence from a study using data from Jordan (Viollaz and Winkler, 2020) indicated that internet adoption increased women's participation in the labor force but had no impact on male labor force participation, and reduced the prevalence of fertility, early marriage, and gender-biased social norms.

Efobi *et al* (2018) obtained empirical evidence suggesting significant positive impacts on female labor force participation of mobile phone penetration, internet penetration, and fixed broadband subscriptions, based on data from 48 African countries for 1990-2014. Similarly, Ngoa *et al* (2021) applied fixed-effects and system-generalized method of moments estimation techniques to data from 48 African countries from 2001-2017 to examine the impacts of ICT on female-labor force participation. The authors found that use of mobile phone and internet had a significant positive impact on female labor force participation. In addition, their results showed that the effect was at its strongest in the industrial sector and was enhanced by financial development and female education.

On the other hand, Bahia *et al* (2021) applied a difference-in-differences estimation method to a panel of household survey data combined with geospatial information on the rollout of mobile broadband coverage in Tanzania and examined the impacts on poverty, household consumption, and labor market outcomes. They found that "*being covered by 3G networks has a large positive effect on total household consumption and poverty reduction, driven by positive impacts on labor market outcomes*." Their results showed that the effects varied by gender, age, and skill level. In particular, they found that high-skilled women benefited from moving from self-employment into non-farm employment, whereas younger and more skilled males gained the most through increased wages and labor force participation. Similarly, Ritika (2021) found that positive effects of ICTs on women were limited to the share of women in the highly skilled labor force but did not affect the female share in the low or unskilled workforce.

2.3. Trade and infrastructure

The literature generally shows that infrastructure exerts a positive impact on international trade (Bougheas *et al*, 1999; Nordås and Piermartini, 2004; Portugal-Perez and Wilson, 2012; Francois and Manchin, 2013; Donaubauer *et al*, 2018; Donaldson, 2018; Trew, 2020). A large body of work focused on the 'transportation-cost channel', concluding that reliable transport infrastructure reduces transportation costs which, in turn, increases trade flows. Other studies considered the role of electrification or access to electricity, and over the last two and a half decades, a rapidly growing body of literature has focused on the impacts of ICT on trade, particularly the effects of mobile phone and internet use.

Bougheas *et al* (1999) investigated the role of infrastructure in a bilateral trade model with transport costs which were assumed to have an inverse relationship with the level of infrastructure. The predictions of their theoretical model showed that "[f]*or pairs of countries for which investment in infrastructure is optimal, the model predicts a positive relationship between the level of infrastructure and the volume of trade*." Martincus *et al* (2017) obtained results suggesting that improvements in transport infrastructure (domestic road network) in Peru had a significant positive influence on firms' exports and employment growth. Similarly, Donaldson (2018) found that India's vast railroad network had a positive impact on the country's interregional and international trade.

Studies have also examined the impact of electrification or access to electricity on trade, either separately or as sub-index for infrastructure (e.g., Donaubauer *et al*, 2018). Access to electricity plays a critical role in firm production, especially in the manufacturing sector (Oseni and Pollitt, 2013; Donaubauer *et al*, 2018; Geginat and Ramalho, 2018; Rehman *et al*, 2020). Since many developing countries rely on the manufacturing sector to produce exportable goods (e.g., automotive and textiles sectors), we would expect a positive link between electricity and trade.

Geginat and Ramalho (2018) examined the effects of procedures, time, and costs associated with first-time electricity connections for small enterprises in 183 countries and found that "*simpler and less costly electricity connection processes are associated with better firm performance in industries with high electricity needs, such as manufacturing motor vehicles*." Similarly, Oseni and Pollitt (2013) investigated the economic costs of unsupplied electricity by focusing on the impacts of power outages in the presence of backup generation, using data from 6854 firms operating in12 African countries. The authors found that "*large firms, firms engaging in exports, and those using the Internet for their operation still suffer higher unmitigated outage costs despite having a higher propensity of investing in backup generation*." Rehman *et al* (2020) also documented the positive impact of electricity on exports. Based on empirical analysis using panel data from a group of South Asian economies, Rehman *et al* (2020) concluded that energy infrastructure (an index which included *per-capita* consumption and production of electric power) had a significant positive long-run impact on exports.

In the last 25 years, studies have increasingly focused on the impact of ICTs. For example, Nordås and Piermartini (2004) examined the effects of the quality of infrastructure on trade performance using a gravity model of total bilateral trade and trade in the automotive, clothing and textiles sectors, and several indicators for the quality of infrastructure. The authors found that while port efficiency appeared to have the largest effects on trade, "*timeliness and access to telecommunication are relatively more important for export competitiveness in the clothing and automotive sector, respectively*." Similarly, Donaubauer *et al* (2018) examined the effects of infrastructure, including ICT, for a panel of 150 developed and emerging economies and found that improving infrastructure quality reduced trade costs and increased international trade flows. After decomposing the effects, the authors found that improved infrastructure stimulated higher export flows relative to domestic flows.

Internet use, web-hosting services, and mobile phones, in particular, have been shown to have a positive impact on international trade. For example, based on time-series and cross-section regression, Freund and Weinhold (2004) obtained results indicating that a "*10 percentage point increase in the growth of web hosts in a country leads to about a 0.2 percentage point increase in export growth*." Similarly, Clarke and Wallsten (2006) found that access to the internet enhanced export performance in developing countries, while Clarke (2008) reported a strong positive association between exporting and internet access at the enterprise level, using data from enterprises in low- and

middle-income countries. Also, Vemuri and Siddiqi (2009) obtained robust evidence in support of a positive and significant impact of ICT infrastructure and use of internet for commercial transactions on international trade.

Dannenberg and Lakes (2014) studied the impact of mobile phone use by farmers in the Mt. Kenya region in Kenya, using data from questionnaires and expert interviews, and found that the use of mobile phones "*stimulated the farmers' possibilities for payment, production, marketing, and knowledge transfer, and their competitiveness and integration in international value chains*." On the other hand, Epo and Nguenkwe (2020) examined the effects of ICT on intra-regional trade in the Economic Community of West African States (ECOWAS) over the period 1994 to 2014 and found that mobile and fixed phones had a positive association with intra-regional trade for both exporting and importing countries.

III. Empirical analysis

3.1. Variable selection, data, and methodology

The dependent variable in this study is the female labor force participation rate (% of total labor force), while the right-hand side variables of primary interest are trade and infrastructure and their interactions. We use the ratio of the sum of a country's exports and imports to its gross domestic product (GDP) to represent international trade (the variable *trade*). We considered three indicators of infrastructure: the percentage of population with access to electricity (the variable electricity), mobile cellular telephone subscriptions per 100 people (the variable mobile), and individuals using the internet (the variable *internet*) as a percentage of total population. The choice of these variables is justified by their use in other studies, as discussed above. Existing literature also provides evidence of the influence of transportation infrastructure (such as roads, buses, trams, and subways) on women's participation in labor markets. Furthermore, as noted above, studies have also found a strong positive association between transport infrastructure and international trade. Unfortunately, there is a remarkable lack of panel (cross-country for several years) data at the macro level on indicators of transport infrastructure, which caused us to exclude this infrastructure from the empirical analysis. On the other hand, data on access to electricity are considered more reliable (Rehman *et al*, 2020).

One of the key factors affecting women's participation in the labor force is fertility. The literature reports that higher fertility rates generally cause (or are associated with) lower female labor force participation, at least in the case of developing countries. For example, Lee and Chung (2008) used data from government surveys in Korea and found that fertility had a negative correlation with labor force participation. On the other hand, some studies have noted the possibility of an endogeneity problem when fertility is used as an explanatory variable, and that causality may run in the opposite direction, from labor force participation to fertility. Nevertheless, even after addressing the problem of endogeneity, fertility still showed a negative impact on female labor force participation.

Chun and Oh (2002) examined the impact of fertility on labor force participation in Korea after instrumenting fertility and found that having children caused the labor force participation rate of married women to fall by 27.5%. De Jong *et al* (2017) estimated the causal effects of fertility on women's employment using data on nearly 250,000 women in SSA, of whom approximately 2% gave birth to twins (and both children survived), and used having twins as an instrumental variable. The

women who had twins were compared with women who had at least one child but did not have twins. Based on results from instrumental variable (IV) estimates, the authors concluded that "*the presence of one additional child under six reduces the odds that the mother participates in the non-farm labor force by 6%*" and noted that having more children, caused women to stay out of the labor market or drop out of it, or opt for a farm job. Bloom *et al* (2009) used abortion legislation to instrument fertility (eliminating legal restrictions on abortion reduced fertility) in a panel of several countries and found that, "*on average, a birth reduces a woman's labor supply by almost 2 years during her reproductive life*". Thus, we would expect the impact of fertility in developing countries to be negative.

In addition to openness to trade, infrastructure, and interactions between trade and infrastructure (based on the discussion in Section 2), we also controlled for fertility rates, the effect of past levels of the dependent variable (inclusion of the lagged value), the effect of time, and the interactions between three region indicators (MENA, SSA and LAC) and openness to trade[2]. The inclusion of interactions of trade with region dummy variables was based on earlier findings (e.g., Baliamoune-Lutz, 2020, 2021) suggesting significant cross-region differences in the effects of trade on women's wages employment. Appendix A contains a description of the variables and data sources.

We used a strongly balanced panel of annual data from 91 developing and emerging economies, covering the period 1990-2018. The sample includes a large group of countries from Asia and LAC, as well as most countries in the MENA and SSA regions. Correlation coefficients for the main variables are reported in Table 1. The displayed figures (which are all statistically significant at the 5-perecent level or better) indicate that linear correlations between female labor force participation and trade, mobile phone subscriptions, and internet use are negative (-0.05, -0.08, and -0.17, respectively) but very low. The correlation with electricity is negative but relatively important in magnitude (-0.52). The correlations between female labor force participation with income and female secondary school enrollments are also negative (-0.51 and -0.28, respectively), while the correlation with fertility is positive (0.26). We note that the correlations between fertility and all other variables (except the female labor force) have the expected (negative) sign and are quite high, except for the correlation with trade (-0.33). Trade has positive correlations with infrastructure indicators, income, and female secondary school enrollment rates. Finally, all three indicators of infrastructure have significant positive association with each other, and with income and female secondary school enrollments.

The methodology we used initially in the econometric analysis consists of estimating the impacts of openness to trade, infrastructure (electricity, mobile phone and internet use), and their interactions on women's participation in the labor force using a fixed-effects (FE) specification. However, to alleviate the problem of potential endogeneity of trade as an explanatory variable, we also performed fixed-effect *instrumental-variable* estimations (using IV-FE estimator) where the variable trade is instrumented.

2. We did not include income and female secondary school enrolments in the estimations due to their very strong negative association (multicollinearity) with fertility rates, and with trade and electricity, respectively (see Table 1).

3.2. Estimation results

3.2.1. Fixed effect estimates

Table 2 reports the main fixed-effects estimation results. We included the lagged dependent variable because the current level of women's participation in the labor force tends to be significantly determined by its past level. The coefficient on the lagged dependent variable is statistically significant (at the 1% level) and positive in all equations. Nearly 40% of the increase in the past level is transmitted to the current level, which suggests the presence of an important persistent component in the behavior of women's labor force participation.

The first column of Table 2 presents a basic model we used to examine the linear effects of trade and infrastructure indicators, along with fertility rates, time, and the lagged dependent variable. We note that while, as expected, the coefficients on fertility and mobile subscription are statistically significant (at the 1% level), and have a negative and positive sign respectively, the effect of trade and internet use is statistically nonsignificant. On the other hand, the effect of electricity, while statistically significant, is negative. The second column of Table 2 displays estimates where we incorporated nonlinearities by including quadratic terms of the variables *trade* and *electricity*. The results indicate that, indeed, these two variables appear to have a curvilinear (U-shape) relationship with women's labor force participation, suggesting that openness and electricity (an indicator of physical infrastructure) have threshold effects. This is a consistent result throughout all estimates.

We then added the interaction between electricity and trade, and it appears to be consistently statistically nonsignificant (columns 4 through 6 of Table 2). In column (4), we included the interplay of trade and mobile phones (the variable 'mobile') and we found that this interaction term shows a positive and statistically significant (at the 5% level or better) effect on (or at least relationship with) female labor force participation. The interplay of trade with internet use also seems to exert a positive and statistically significant effect on women's participation in the labor force, even after we controlled for the interplay of trade and mobile phones (columns 5 and 6 of Table 2), suggesting that, through their interplay with increased openness to trade, these two indicators of ICT may help increase female labor force participation in complementary ways. As noted earlier, the numbers in Table 1 indicate that there is a strong positive linear correlation (0.84) between internet use and mobile phone subscriptions.

In the last column of Table 2, we explored regional differences by including the interaction between trade and region dummy variables. We found that trade in MENA has an additional negative impact on female labor force participation, which increases the threshold level above which openness to trade would raise women's participation in the labor force. On the other hand, the interplay of trade and the dummy variable for LAC exerts a strong positive impact; thereby reducing, or even invalidating, the threshold value requirement for positive effects of trade on female labor force participation. The results do not show any significant region-specific impact in SSA.

3.2.2. IV-FE estimates

Some studies noted that trade (imports and exports) may potentially be endogenous to female labor force participation (Autor *et al*, 2013; Amin and Islam, 2021), Unfortunately, it was not possible to find a suitable instrument for trade using panel data for a large group of countries. However, to try to minimize the impact of a potential endogeneity problem, we used the variable 'trade' with its lagged values and re-estimated the main equations that yielded the results reported in Table 2, using an instrumental variable fixed-effects model (IV-FE) and considering possible additional effects from trade in MENA, LAC and SSA. Table 3 reports the main IV-FE estimates. The results displayed in Table 3 confirm those reported in Table 2. These results indicate that trade openness and access to electricity both have a non-linear (U-shape) association with female labor force participation, while the interaction between trade openness and ICT indicators exerts a positive impact. The positive effects from openness to trade are stronger in LAC and much weaker in the MENA region (as reflected in the magnitudes and signs of the coefficients showing the interaction between trade and the region dummy for LAC and MENA, respectively). We also found, as expected, a robust negative and substantial effect of fertility on women's participation in the labor force.

IV. Concluding Remarks

We used data from 91 developing and emerging economies and performed panel data estimations to explore the impacts of trade and infrastructure, as well as the effects from their interactions, on female labor force participation. We used openness to trade as our indicator of a country's level of international trade, and three indicators of infrastructure: access to electricity, mobile phone subscriptions, and internet use. Results from two estimation techniques are consistent and provide evidence of significant roles of trade and infrastructure in boosting women's labor force participation. Since female labor force participation is defined (in this paper) as a share of total labor force, the results also suggest that trade and infrastructure can reduce gender inequality in labor markets. However, the effects of trade and infrastructure are nonlinear; they become positive only after a high threshold level. The results suggest that as countries with low trade volumes begin to increase their openness to trade, women's participation in the labor force may initially fall. Similarly, access to electricity has a positive effect on female labor force participation but only when access is very high.

We found that interaction of access to electricity with openness to trade does not have a statistically significant impact on women's participation in the workforce. While the literature has documented a strong positive association (as discussed in Section 2) between trade and access to electricity, our results did not show that these two factors are complementary in their impacts on female labor force participation. Additionally, we found an independent positive effect from mobile phone subscriptions (in most estimations), but not from internet use. However, we found positive impacts from the interplay between these two ICT (infrastructure) indicators and trade, suggesting that increased openness to trade and improved access to ICT (internet and mobile phones in particular) stimulate women's participation in the workforce.

The results on the positive independent effects of trade and access to electricity are consistent with findings in existing studies (Dinkelman, 2011; Chen *et al*, 2013; Grogan and Sadanand, 2013; Dasso and Fernandez, 2015; Benguria and Ederington, 2017; Tenezakis and Tritah 2020; Sedai *et*

al, 2021). Similarly, our results are, for the most part, consistent with studies reporting a positive impact from use of mobile phones (Efobi *et al*, 2018; Bahia *et al*, 2021; Ngoa *et al*, 2021). On the other hand, while several studies found internet use had a significant independent positive impact on women's participation in labor markets (Efobi *et al*, 2018; Viollaz and Winkler, 2020; Ngoa *et al*, 2021), our results did not show an independent positive effect. However, as noted earlier, internet use and mobile phone subscriptions exert a positive impact on female labor force participation through their interactions with openness to trade.

It is worth noting that the effect of fertility on female labor force participation is, as expected, negative and significant in all estimations, and the time effect is statistically significant and positive, possibly reflecting progress in other determinants of female labor force participation. We also note that the lagged value of the dependent variable (female labor force participation) is statistically significant and has a high value, indicating that nearly 40% of the change in female labor force participation in any given year is transmitted to the following year. This result suggests that there is a significant persistent component in the behavior of this variable in spite of progress in other determinants.

Overall, the findings in this paper point to the importance of infrastructure in enhancing the gains from trade and increasing women's labor force participation. Policymakers should recognize the important role of infrastructure in enabling men and women to increase their participation in the labor force, especially when the economy increases its openness to trade. This is because expanding trade causes sectoral shifts and often leads to relocation of firms and workers, hence the important role of the quality and availability of infrastructure.

The results we obtained suggest that there is a role for policy in boosting women's supply of labor through investment in the appropriate infrastructure. As noted earlier, many studies have found that trade had engendered effects that were biased against women in labor markets. It is plausible that some types of infrastructure affect men and women differently, and that these differences could contribute to our understanding of why trade affects men and women differently. In regions where female labor force participation is remarkably low (MENA and South Asia), policymakers should identify the infrastructure that is particularly helpful to women in their specific country and improve its quality and availability.

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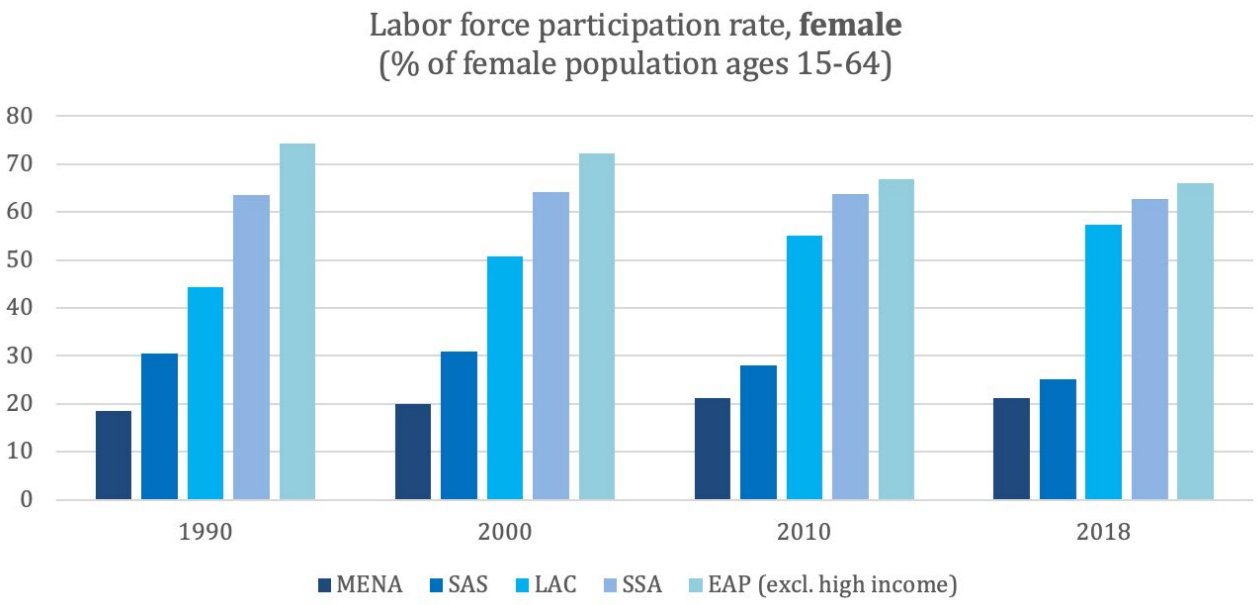
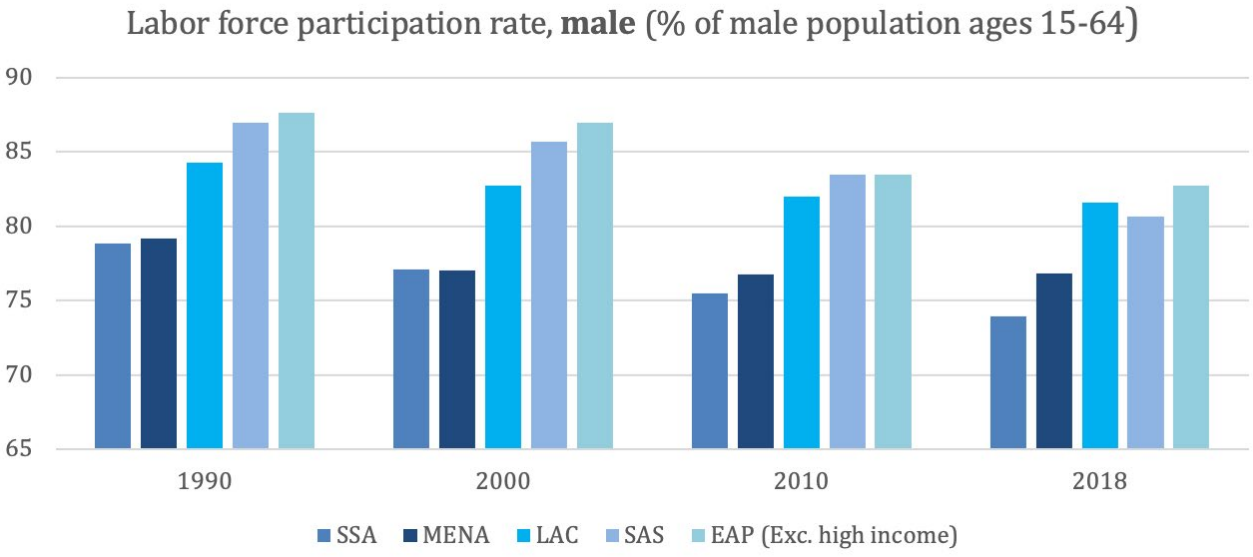
Figure 1a



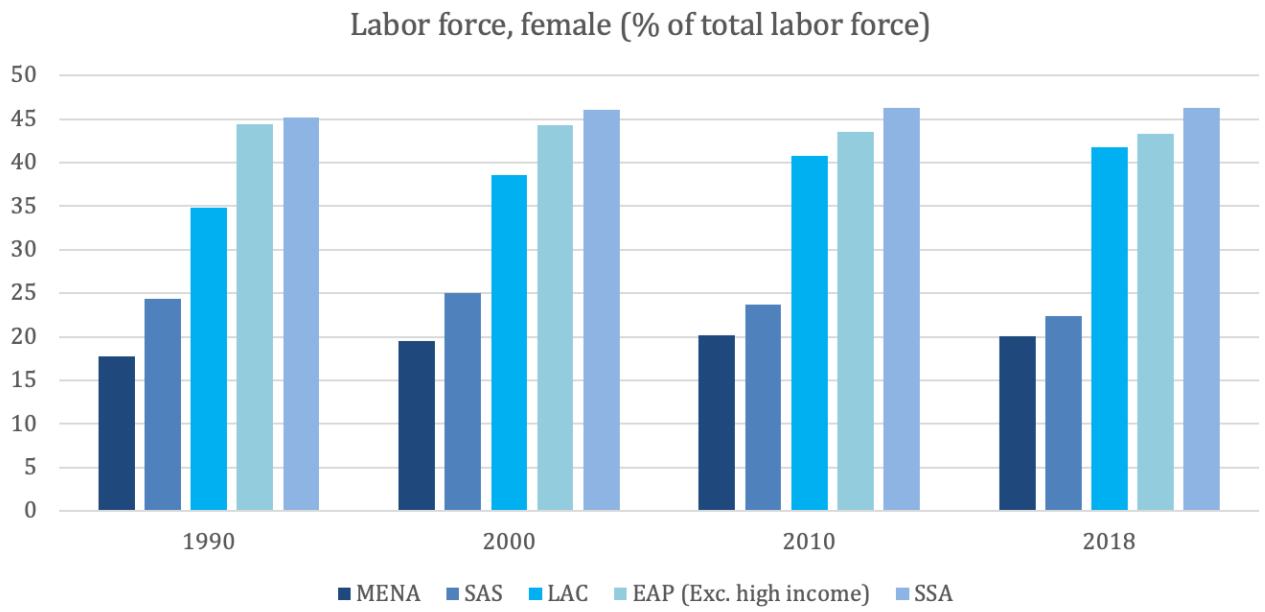
Source: Word Development Indicators database online, World Bank (accessed on February 3, 2021)

Figure 1b



Source: Word Development Indicators database online, World Bank (accessed on February 3, 2021)

Figure 2



Source: Word Development Indicators database online, World Bank (accessed on February 3, 2021)

Table 1: Pairwise correlation*

	female Labor force participation (% of total)	fertility	trade	electricity	internet	mobile	income (log)
fertility	0.255						
trade	-0.045	-0.328					
electricity	-0.520	-0.816	0.268				
internet	-0.167	-0.547	0.336	0.545			
mobile	-0.079	-0.504	0.305	0.475	0.841		
income (log)	-0.511	-0.714	0.852	0.434	0.592	0.493	
female secondary school enrollment	-0.279	-0.836	0.246	0.844	0.637	0.603	0.836

Details on source of data and variable description are in Appendix A.
* All P values are less than 0.001 except the correlations of trade with the female labor force, which has a P value of 0.024.

Table 2: Trade, infrastructure, and women's participation in the labor force: Fixed-effects estimates

Dependent variable: Labor force participation, female (% of total)

	(1)	(2)	(3)	(4)	(5)	(6)
lagged dep. var.	0.397***	0.387***	0.387***	0.387***	0.389***	0.384***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
time	0.052***	0.071***	0.072***	0.082***	0.081***	0.071***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
fertility	-0.524***	-0.614***	-0.061***	-0.636**	-0.635**	-0.649***
	(0.097)	(0.096)	(0.094)	(0.096)	(0.096)	(0.095)
trade	0.0005	-0.0156***	-0.016	-0.071***	-0.131***	-0.018**
	(0.001)	(0.002)	(0.003)	(0.009)	(0.009)	(0.007)
electricity	-0.033***	-0.069***	-0.033***	-0.069***	-0.071***	-0.064***
	(0.004)	(0.009)	(0.004)	(0.009)	(0.009)	(0.010)
internet	0.003	-0.0028	-0.003	-0.0049	-0.009**	-0.006*
	(0.003)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
mobile	0.0045***	0.0027*	0.0026*	-0.003	-0.0022	-0.003
	(0.001)	(0.002)	(0.001)	(0.0024)	(0.0024)	(0.0025)
trade_squared		0.00005***	0.00004***	0.00004***	0.00003***	0.00004***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
electricity_ squared		0.0003***	0.0003***	0.0004***	0.0004***	0.0003***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade x electricity			0.0002	0.00002	-0.00001	-0.00003
			(0.0004)	(0.00004)	(0.00004)	(0.00006)
trade * mobile				0.00003***	0.00003**	0.00004***
				(0.000)	(0.00001)	(0.000)
trade * internet					0.00005***	0.00004**
					(0.000)	(0.00002)
MENA x trade						-0.0158***
						(0.004)
SSA x trade						0.0035
						(0.005)
LAC x trade						0.0255***
						(0.005)
R-sq						
Within	0.57	0.58	0.58	0.59	0.59	0.60
Between	0.98	0.98	0.97	0.98	0.98	0.95
Overall	0.95	0.95	0.94	0.94	0.95	0.93

Number of observations: 2001
Details on source of data and variable description are in Appendix A. Standard errors (in parentheses) are clustered at the country level.
* indicates significance at 0.10 ** indicates significance at 0.05 and *** indicates significance at 0.01.

Table 3: Trade, infrastructure, and women's participation in the labor force: IV-FE estimates

Dependent variable: Labor force participation, female (% of total)

	(1)	(2)	(3)	(4)
lagged dep. var.	0.380***	0.381***	0.383***	0.383***
	(0.012)	(0.012)	(0.013)	(0.012)
Time	0.059***	0.060***	0.069***	0.070***
	(0.011)	(0.011)	(0.011)	(0.012)
Fertility	-0.647***	-0.650***	-0.652**	-0.674**
	(0.096)	(0.096)	(0.096)	(0.096)
Trade	-0.018***	-0.023***	-0.019***	-0.018***
	(0.004)	(0.007)	(0.005)	(0.005)
Electricity	-0.062***	-0.066***	-0.064***	-0.064***
	(0.009)	(0.010)	(0.009)	(0.009)
Internet	0.0004	0.0003	-0.0056	-0.0063*
	(0.003)	(0.003)	(0.004)	(0.004)
Mobile	0.0031**	0.0029**	0.0027**	- 0.0028
	(0.001)	(0.0014)	(0.0013)	(0.0024)
trade_squared	0.00005***	0.00005***	0.00004***	0.00004***
	(0.000)	(0.000)	(0.000)	(0.000)
electricity_squared	0.0003***	0.0003***	0.0003***	0.0003***
	(0.000)	(0.000)	(0.000)	(0.000)
MENA x trade	-0.0176***	-0.0179***	-0.0170***	-0.0181***
	(0.005)	(0.005)	(0.005)	(0.005)
SSA x trade	0.0011	0.0047	0.0039	0.0033
	(0.004)	(0.006)	(0.004)	(0.004)
LAC x trade	0.0235***	0.0236***	0.0250***	0.0250***
	(0.006)	(0.005)	(0.006)	(0.006)
trade x electricity		0.0006		
		(0.0006)		
trade * internet			0.00006***	0.00005**
			(0000)	(0000)
trade * mobile				0.00003**
				(0000)
R-sq				
Within	0.59	0.59	0.60	0.60
Between	0.95	0.95	0.95	0.95
Overall	0.93	0.93	0.93	0.93

Number of observations: 1986
Details on source of data and variable description are in Appendix A. Standard errors (in parentheses) are clustered at the country level.
* indicates significance at 0.10 ** indicates significance at 0.05 and *** indicates significance at 0.01.

Appendix A

Variable description and data sources

- female labor force participation (% of total labor force): Female labor force as a percentage of the total labor force show the extent to which women are active in the labor force. Labor force comprises people ages 15 and older who supply labor to produce goods and services during a specified period. Source: International Labor Organization Labor Statistics online database.

- trade: Openness to international trade (in log) measured as the sum of exports and imports of goods and services, measured as a share (%) of gross domestic product (net of exports to developed countries). Source: World Bank World Development Indicators online database.

- Electricity: Access to electricity (% of population); the percentage of population with access to electricity. Electrification data are collected from industry, national surveys and international sources. Source: World Bank World Development Indicators online database.

- mobile phones: Mobile cellular subscriptions (per 100 people). These are subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology. The indicator includes (and is split into) the number of postpaid subscriptions, and the number of active prepaid accounts (i.e., that have been used during the last three months). Source: International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database

- Internet: Individuals using the Internet (% of population) are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc. Source: International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database.

- fertility: Total fertility rate (births per woman) represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year. Source: World Bank World Development Indicators online database.

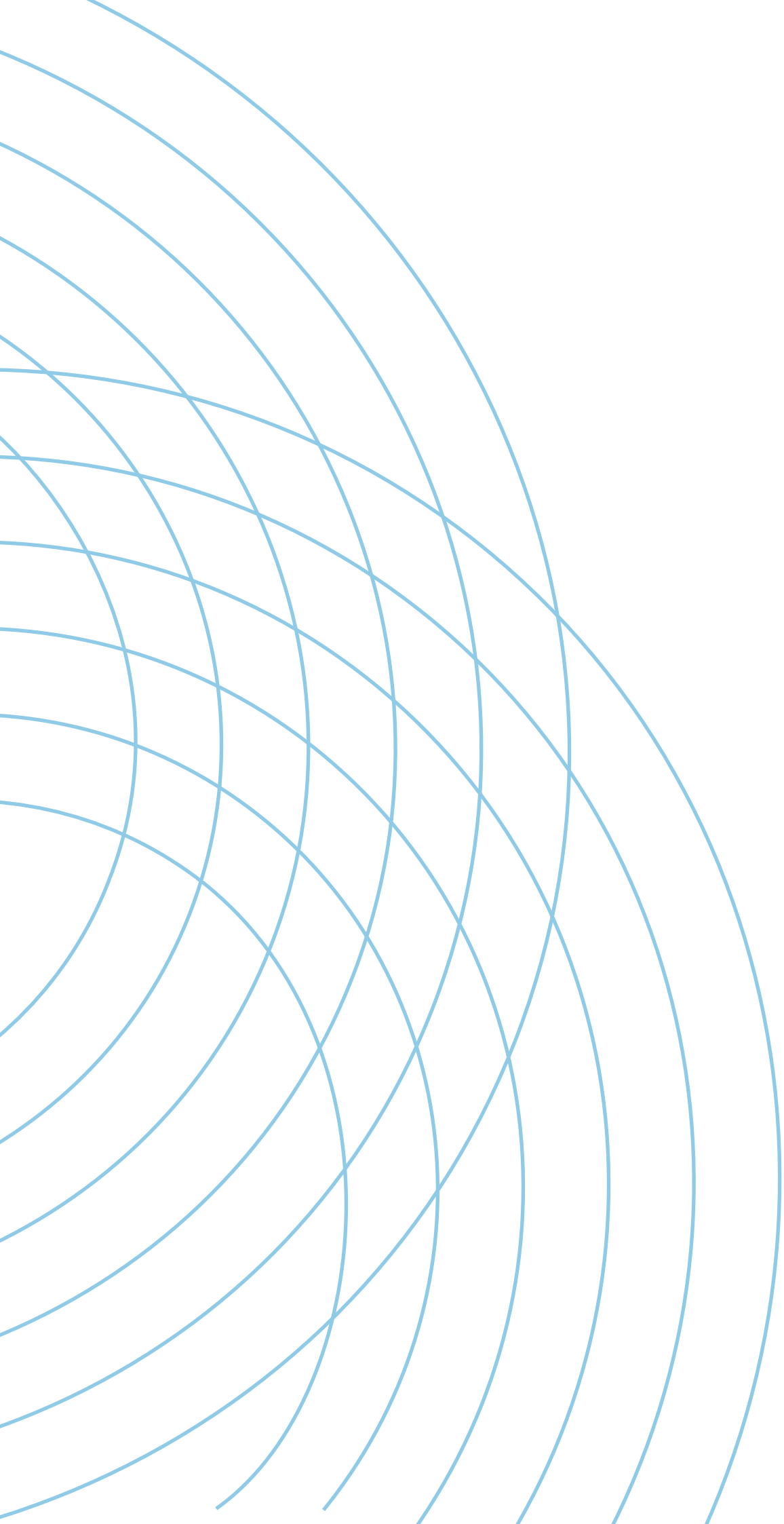
- female secondary school enrollment: Female school enrollment, secondary (% gross). This is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of secondary education level. Source: World Bank World Development Indicators online database.

- Income: GDP per capita (in log) based on purchasing power parity (PPP). Source: World Bank World Development Indicators online database.

- LAC: Dummy variable for Latin America.

- MENA: Middle East and North Africa

- SSA: Dummy variable for sub-Saharan Africa.



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