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The relationship between knowledge accumulation and gender norms

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Gender norms, encompassing social and cultural attitudes that dictate suitable behaviors for women and men, are pivotal in shaping societal dynamics. This paper explores the intricate relationship between knowledge accumulation, as reflected in a nation's economic complexity, and its gender norms. Drawing on the revealed preferences of a substantial cohort, totaling 64,954 individuals from up to 49 countries, and their respective countries' economic complexity indices, we uncover a non-trivial relationship. At lower levels of economic complexity, there exists an inverse correlation between less rigid gender norms and technological sophistication. This suggests that the initial stages of knowledge accumulation coincide with inflexible gender norms, particularly regarding women's roles within households. However, as economic complexity surpasses a certain threshold, this correlation reverses. Further knowledge accumulation aligns with more adaptable gender norms, indicating a shift towards less rigidity, especially concerning women's roles in the public sphere. These findings underline the connection between economic development and shifting gender norms. Notably, while economic complexity catalyzes a transition towards less rigid norms regarding women's household roles at lower stages, it is only at a certain threshold that significant changes in norms pertaining to women's public roles become evident. This study contributes to understanding the evolution of gender norms in the context of economic development. By shedding light on the intricate dynamics between knowledge accumulation and gender norms, it emphasizes the significance of considering socioeconomic factors in addressing gender norms. Findings have implications for policymakers and stakeholders offering valuable insights into the mechanisms driving societal change.

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Introduction

Economic complexity is a measure that aims to capture the diversity and complexity of a country's productive capabilities (Hidalgo and Hausmann, 2009). A country's economic complexity index (ECI) is calculated based on the diversity of exports a country produces and their ubiquity, as well as the number of countries able to produce such goods. Countries that can sustain a diverse range of productive know-how, including sophisticated and unique knowledge, can produce many complex products that few other countries can (e.g., supercomputers, planes, electric cars). Making those products requires individuals with different know-how or person-bytes to interact with one another. Hence, despite being a good predictor of economic growth, economic complexity focuses on skill intensity or person-bytes aspects of the economy. In 2021, the United States of America ranked as the 5th richest economy per capita and 14th in the ECI ranking. India ranks 104th for GDP per capita and 42nd in the ECI ranking. China ranks as the 47th most prosperous economy and the 18th most complex country in the ECI ranking. Clearly, the differences across the economies of the United States, India, and China do not lie only in GDP per capita but also in the ability of their inhabitants to produce complex and unique products.

In this paper, we advance the hypothesis that economic complexity (ECI) is associated with cultural changes in general and gender norms in particular. Taking a multilevel perspective, as in the Social Ecological Model (Bronfenbrenner, 1977), we argue that economic complexity expands individuals' knowledge, choices, and opportunities, thereby linking it with less rigid gender norms. We believe two key factors shape this relationship. Firstly, technological advancement substantiates the notion that men and women possess similar labor market prospects, thereby fostering more flexible family roles. Advanced technologies may increase productivity, mitigate differences in physical labor and demands, and facilitate greater access to education (e.g., via freeing more time from e.g., household-related jobs or child-caring), enabling women and men to pursue a wider range of career paths. Moreover, new technologies may increase the demand for skills that are not inherently gender specific. Secondly, individuals with substantial human capital (often measured as knowledge, skills, and abilities acquired through education, training, and experience) in complex economies are more likely to advocate for gender equality, as they are more likely to believe in or perceive the changing economic prospects of women in both household and work settings.

Notably, other factors can always be at play as underlying forces. We thus argue that economic complexity is one of the drivers, motivated by evidence in the literature suggesting the interplay between the complexity index and human capital. For instance, Zhu and Li (2017) have found that human capital has a positive effect on economic growth and interacts positively with economic complexity. Additionally, countries with economic structures geared towards complex products have lower levels of income inequality, and human capital magnifies this correlation (Lee and Vu, 2020).

The results of our study suggest a correlation between beliefs about gender norms within the household and the level of economic complexity in the country. Furthermore, our analysis reveals that economic complexity is linked to the public role of women in society, encompassing areas such as politics and the labor market. However, this association necessitates a high level of economic sophistication to be fully understood. Additionally, our research uncovers a connection between economic complexity and changes in the perceived attractiveness of certain features of women. This correlation suggests a shift in the range of traits considered appreciable for women, ultimately aligning

with the progression of egalitarian gender norms. Interestingly, this interplay, as will be further discussed below, is not straightforward, and our findings suggest a potentially non-linear relationship.

This is the first study that hypothesizes about and quantifies the link between economic complexity and gender norms to the best of our knowledge. Prior contributions have examined the historical emergence (Almond and Edlund, 2008; Boserup, 1970, Abrevaya, 2009, Alesina et al. 2013, Hansen et al. 2015), transmission (Fernández et al. 2004, Fernández and Fogli, 2009, Blau et al. 2013), persistence (Grosjean and Khattar, 2019) and change of the cultural norms related to gender norms and gender roles (Goldscheider et al. 2015, Fernández, 2013). Gender norms, which involve the allocation of distinct social roles to men and women along with a division of labor based on their sexes, are a universal aspect of human societies. In other words, all known societies have some form of gender roles, although the specific nature of these roles varies across different cultures.

In pre-industrial societies, recent research on human burial has shown that inquiry into whether the division of labor is rooted in gender (typically influenced by biological cues but molded by a combination of societal norms and individual expression) within human populations remains inadequately studied and unresolved (Anderson et al. 2023). The notion of the male breadwinner nuclear family as a universally traditional family structure is strongly linked with Western European industrialization. This family model depends on specific economic conditions, including increased agricultural productivity and industrialization. This particular division of labor emerging with industrialization reinforced rigid gender roles (Sear, 2021). The industrial revolution marked a shift from localized household production to market-driven productivity, influenced by changing societal preferences, with strong variations among social classes and regions. Social norms played a significant role in shaping the decision to become a housewife, often influencing societal expectations more than factors like childbirth or wealth (van Poppel et al. 2009). It is crucial to recognize that family structures vary based on economic conditions and can be very different in other types of economies such as subsistence agriculturalists. Women often take on a significant portion of the daily agricultural tasks such as planting, weeding, and harvesting (Enete et al. 2002) or small fisheries (Harper et al. 2020). As a result, women play a substantial role in resource production. In hunter-gatherer societies, clear gender roles and a sexual division of labor are evident (Griffin and Griffin, 1992). Men typically specialize in hunting large game, while women specialize in gathering plant foods and hunting small game. The extent of women's involvement in hunting can be a subject of debate, but it is generally observed that men take the lead in large game hunting in most hunter-gatherer communities. Childrearing and the physical demands of pregnancy often limit women's mobility and, consequently, their capacity to engage in large-game hunting. As a result, women tend to adopt less risky foraging strategies and focus on collecting stationary resources like plants. While adult men contribute more calories to the overall community diet, the plant foods gathered by women also play a significant role in nutrition.

More broadly, in pre-industrial societies, cultural values and traditions play a significant role in defining masculinity and the role of men and fathers in society. Different cultures and traditions have varying views on gender roles and the involvement of fathers in child-rearing. For instance, fathers' involvement in direct childcare can vary among different hunter-gatherer societies (Hewlett, 1992; Wood and Marlowe, 2013). While women typically take on the primary caregiving role for infants, some hunter-gatherer communities have fathers who actively

participate in infant caregiving. As boys grow older, they often start accompanying their fathers and other adult men on hunting expeditions. This practice means that, after a certain age, boys may spend more time with their fathers than with their mothers. These observations challenge the notion that the concept of a "caring male role" is solely a result of the gender revolution that occurred after the industrial era. In 1970, Boserup presented the hypothesis that rigid gender norms dictating the male bread-winner model may partly originate from the introduction of plow agriculture and men's control over it based on their greater physical strength. The long-term effects of the use of plows are still traceable in cultural norms today because some of these norms show inertia and thus are transmitted from parents to their children, as shown in studies using migrants' self-reported attitudes (Alesina et al. 2013).

In industrialized economies, female labour participation and economic growth were closely related (Doepke and Tertilt, 2009; Duflo, 2012) driving greater demand for labor due to structural economic shifts (Goldin, 1995) and advancements in reproductive technology (Galor and Weil, 1996). In turn, economic growth and some technological advancements managed to ease household labor and enhanced paid labor. Firstly, technological advancements such as washing machines, vacuum cleaners, and kitchen appliances automated many traditional household chores that were once time-consuming and physically demanding. These advancements significantly reduced the time and effort required for housework. Consequently, women were no longer tied to the home for extended periods solely to perform domestic tasks. This increased efficiency meant that women had more time and energy available to pursue activities outside the home, including participation in the labor market. As the extensive burden of housework was alleviated, the rigid gender roles that confined women to domestic duties began to loosen. Women gained the freedom to explore opportunities beyond the house, including education, employment, and engagement in public life. As women gained more time and flexibility due to reduced household labor demands, they increasingly entered the labor market. Technological advancements not only made housework more manageable but also created opportunities for women to pursue careers and contribute to the workforce (Hertog et al. 2023). Secondly, the advent of mass high school education and new technologies contributed to an increased demand for clerical workers, and these jobs were increasingly taken on by women. Moreover, because these jobs tended to be cleaner and safer, the stigma attached to working for a married woman diminished. Furthermore, expanding public education raised the demand for more teachers, office workers, and salespeople required by growing industrial and commercial enterprises. While teaching and clerical tasks were previously performed by men, employers realized that they could hire women for these occupations at lower salaries.

In the 1970s, there was a surge in the number of married women entering the labor force, accompanied by new opportunities for female workers in traditionally male-dominated occupations, thereby reducing the strict segregation of women into specific job roles (Yellen, 2020). However, economic growth has not entirely liberated women from primary responsibilities for housework, nor has it reduced the time spent on house-related tasks (Mandel et al., 2020). Consequently, while economic growth is linked to female labor participation and gender norms, the timing and reasons behind changes in household and public space gender norms remain uncertain. The concept of public-private spheres delineates societal activities and responsibilities into two distinct realms. The public sphere encompasses political, economic, and social activities outside the home, while the private sphere encompasses domestic and family life within the home.

This division has historically been associated with gender roles (Habermas, 1991). Previous studies have also highlighted distinctions between private-sphere and public-sphere attitudes (Goldscheider et al. 2010). It has been argued that changes in gender roles within these spheres have differential impacts on fertility: increased gender equality in the public sphere may lead to lower fertility as families navigate the balancing act between work and caregiving. Conversely, increasing gender equality in the private sphere potentially strengthens families and enhances fertility.

In this paper, we advance the hypothesis that knowledge accumulation, captured by the index of economic complexity, is associated with culture and norms. We posit that ultimately higher levels of economic complexity are associated with more egalitarian gender norms. We also find that this interplay differs for gender norms in the family and gender norms in the public sphere. Interestingly, our findings suggest that while less rigid norms in the household are observable across a wide range of societies beyond a certain level of economic complexity, these flexible norms regarding women's roles in society are only evident when economic complexity is high.

While the adoption of more egalitarian gender norms often initiates within households, it is an integral part of the broader social fabric, with the transition of these norms from private to public spheres being a gradual and evolving process (Hidalgo et al. 2007). Within the confines of homes, individuals are exposed to changing dynamics in gender roles and responsibilities, gradually recognizing the value of shared responsibilities and equal opportunities for men and women. These shifts in mindset and behavior are influenced by various factors. They can be responses to increased educational attainment, exposure to diverse ideas, and recognition of individual labor market prospects regardless of gender. They can also result from exogenous shocks or structural changes that alter the household's balance in productivity or role models. Although these changes may initially take root either at the household or societal level, depending on the type of "shock", it is crucial for them to be endorsed at the household level to spread throughout society. The family serves as one of the primary institutions responsible for the reproduction of society, both biologically and socially, through the transmission of culture, making it instrumental in this regard. Subsequently, evolving gender norms gain traction through interactions with peers, communities, media, workplaces, and various societal institutions.

In Fig. 1, we have employed a simple graph to visualize the relationships between the major variables discussed. The most intricate relationship depicted is the one linking economic growth with enhanced education and expanded labor force participation. We do not extensively analyze this aspect, as each variable has been the subject of extensive research and is influenced by a multitude of factors, both endogenous (such as policies) and exogenous (e.g., wars). Therefore, we consider the interplay between economic growth, education, and labor participation as given, focusing instead on how enhanced and broadened education, facilitated by knowledge accumulation, ultimately manifests in increased economic complexity. This knowledge accumulation is inherent in complex societies and is reflected in the Economic Complexity Index (ECI). Subsequently, complex societies, through channels like media and peer effects, contribute to the development of less rigid gender norms, as evidenced by revealed preferences in surveys. It should be noted that we have employed this figure solely to visualize and explain the relationships between major variables of interest, particularly focusing on the intricate link between economic growth, education, labor force participation, and ultimately, gender norms as mediated through economic complexity. Therefore, it is not used for causal inference purposes.
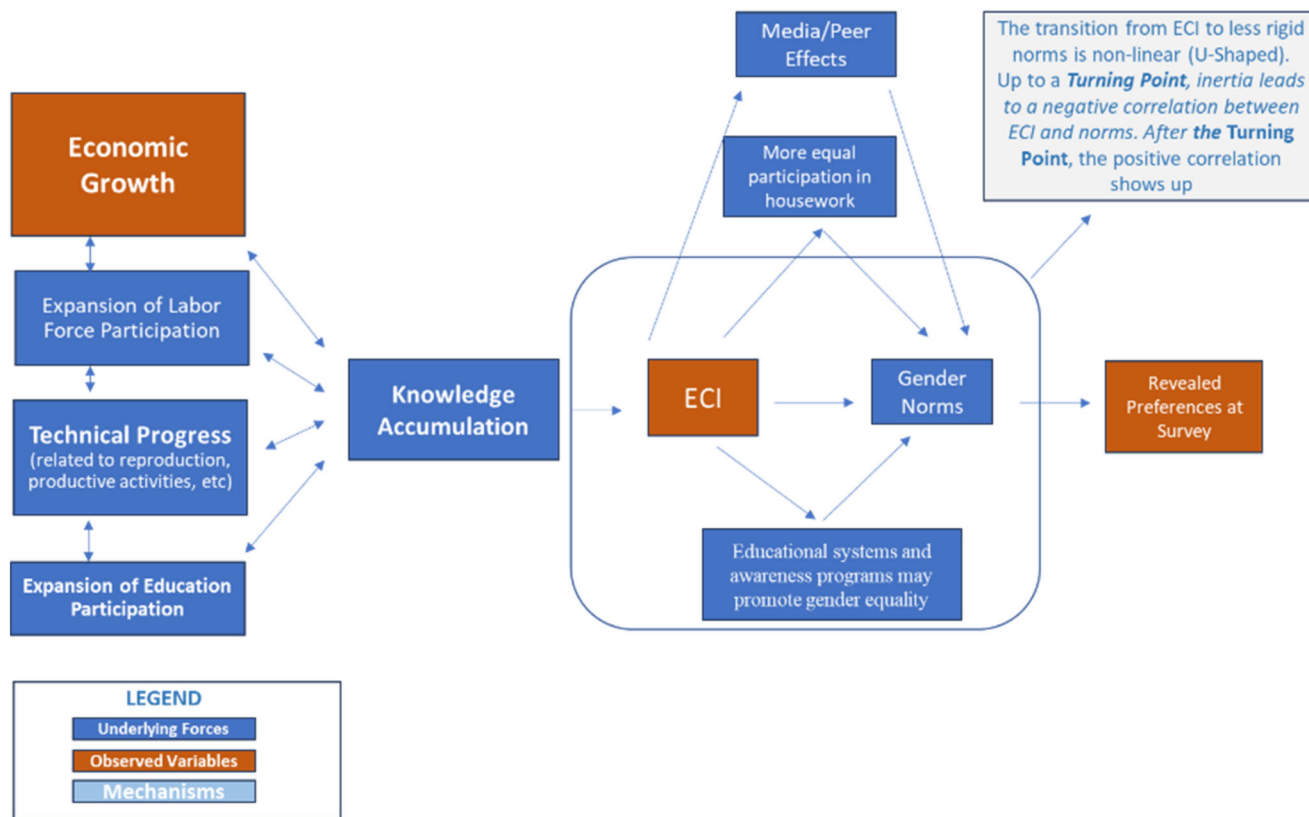
Fig. 1 The variables and the associated mechanics. The interplay of technical progress, economic growth, and knowledge accumulation on economic complexity and on gender norms.

To test our hypotheses, we use a comprehensive dataset documenting the attitudes of individuals from various countries. Specifically, we explore the relationship between economic complexity at the country level and individual-level data reflecting cultural norms. To measure gender norms, we employ the integrated dataset of the European Values Study and the World Values Survey. This dataset, spanning from 1981 to 2019 (though not all years and questions are available for each country), offers insights into the demographic characteristics and cultural attitudes of individuals across several countries worldwide. To capture a rich picture of attitudes towards women, we examine five questions that reflect various norms related to gender roles within the household. The first question probes whether women's desire primarily revolves around home and children, as opposed to a job. Similarly, the second question explores whether having a job is perceived as the optimal path for a woman to achieve independence. The third question delves into perceptions about marriage dynamics, particularly whether households where a woman earns more than her husband are expected to encounter problems. The fourth question assesses attitudes towards fathers' capability to care for children. Lastly, the fifth question investigates attitudes towards abortion when the woman is unmarried. We focus on each question independently, as they are conceptually grouped together in Table 1. Other related questions in the survey were excluded due to insufficient responses.

We proxy knowledge accumulation with the improved ECI from the Observatory of Economic Complexity (OEC) available at https://oec.world/en. The ECI begins by assessing the revealed comparative advantage of a country in a specific product compared to the rest of the world. This is achieved by comparing the share of a product in a country's total exports to the percentage of that product in global exports. Subsequently, the ECI aggregates a country's revealed comparative advantage values across all its

exported products. In doing so, it not only considers the comparative advantage in individual products but also the complexity of those products. Therefore, the ECI serves as a measure of how diversified and complex a country's production basket is. A high ECI indicates that a country produces and can export a broader range of complex products, such as electronics, machinery, and chemicals, which are produced by few countries (Hidalgo and Hausmann, 2009; Hidalgo et al. 2007).

Our findings reveal a non-linear relationship between economic complexity and gender norms within the household, characterized by a U-shaped function. In contexts where economic complexity and knowledge are limited, further increases are correlated with more rigid gender norms. However, in settings with high economic complexity, additional increases are associated with less rigid gender norms. The relationship between Economic Complexity Index (ECI) and gender norms in society, particularly pertaining to women's leadership, business executive roles, and participation in politics, exhibits a distinct pattern. Economic complexity is linked with gender norms regarding women in the public sphere, but this association becomes significant only in countries with relatively high income per capita. In other words, while economic complexity correlates with gender norms within the household, it requires further increases in ECI for less rigid gender norms to manifest in the public sphere.

Methods

Empirical analysis. The empirical analysis is structured to evaluate our primary and ancillary hypotheses. In our econometric specification, each individual is linked with their country's level of Economic Complexity Index (ECI). Drawing inspiration from the Social Ecological Model (SEM) (Bronfenbrenner, 1977), we adopt a multilevel perspective to comprehend and analyze the diverse factors influencing gender norms. The SEM typically

Table 1 Benchmark Analysis: ECI and gender norms in the household.

	(1) Women want a home and children	(2) Job best way for women to be independent	(3) Problem if women have more income	(4) Fathers suited looking after children	(5) Abortion when woman is not married
ECI	−0.435*** (0.148)	−0.771*** (0.110)	−1.842*** (0.030)	−3.704*** (0.103)	−2.329*** (0.033)
ECI Squared	1.095*** (0.065)	0.415*** (0.053)	4.090*** (0.067)	1.443*** (0.044)	1.031*** (0.022)
Turning Point	0.19	0.92	0.225	1.28	1.12
Observations	30,136	30,542	64,954	26,727	33,744
R-squared	0.188	0.049	0.098	0.077	0.187

(i) The dependent variables take values: 1–4 (Columns 1–4), 0-1 (Column 5). In all columns, lower values imply less favorable/more conservative attitudes towards women and higher values denote more favorable/modern attitudes towards women (see Table A5 in Appendix); (ii) All econometric specifications include individual and country controls (see in the text), country and wave/year fixed effects; (iii) Robust standard errors in parentheses; (iv) *p < 0.05; **p < 0.01; ***p < 0.001.

Table 2 ECI and gender norms in the public space.

	(1) Men should have more right to a job than women	(2) Men make better political leaders than women do	(3) Men make better business executives than women do	(4) Women have the same rights as men
ECI	−0.031 (0.081)	0.077 (0.079)	−0.133 (0.242)	−0.761 (0.663)
ECI Squared	0.050 (0.061)	0.083 (0.076)	−0.077 (0.145)	−0.574 (0.423)
Observations	252,217	208,590	118,274	116,976
R-squared	0.121	0.234	0.238	0.098

(i) The dependent variables in Columns 1–4 take values, 0-1 (Column 1), 1–4 (Columns 2 and 3), and 1–10 (Column 4). In all columns, lower values imply less favorable/more conservative attitudes towards women and higher values denote more favorable/modern attitudes towards women (see Table A5 in Appendix); (ii) All econometric specifications include individual and country controls (see in the text), country and wave/year fixed effects; (iii) Robust standard errors in parentheses; (iv) *p < 0.05; **p < 0.01; ***p < 0.001.

encompasses interconnected levels or systems, with each representing distinct aspects of an individual's environment. These levels are often depicted as concentric circles, with the individual at the core, and expanding outward to encompass broader social influences. In our framework, we first consider the individual level, which focuses on personal characteristics such as knowledge, attitudes, and beliefs. Recognizing that personal factors shape individual choices and actions, we incorporate a series of individual variables into our econometric specification. The second level is the societal level, which encompasses broader societal factors including cultural norms, economic policies, laws, and media influences. This outermost circle is captured by the macro variables in our specification. Our primary explanatory variable is ECI, and we hypothesize its association with gender norms, as measured by individuals' responses to a comprehensive set of relevant questions in our micro-level dataset. Specifically, our analysis utilizes a joint dataset combining both the European Values Study (EVS) and the World Values Survey (WVS). The EVS, a long-running survey since 1981 conducted every nine years, covers a wide range of European countries. Meanwhile, the WVS comprises nationally representative surveys conducted in nearly 100 countries, encompassing diverse cultural and economic contexts.

It is important to note that the sample of countries differs across regressions due to the limited availability of each question in each wave. Tables A1-A4 in the Appendix provides a report on the sample of available countries employed in each regression. Furthermore, our integrated EVS-WVS sample lacks the panel dimension, meaning the data does not track the same individuals over time but rather different individuals within the same country over time. While we cannot leverage a panel dimension, we account for the time dimension by controlling for survey wave fixed effects in all tables, capturing common shocks that may have affected a country in a particular period. Additionally, we merge each individual with the corresponding ECI index at the time of their questionnaire response, thus capturing the time-varying nature of

ECI as well. Moreover, it is worth highlighting that we do not have the panel dimension in the integrated EVS-WVS sample. That is, the data does not follow the same individuals over time but rather different individuals in the same country over time. Despite this limitation, there is a time dimension, meaning some countries in our sample appear in different waves. The analysis in all tables considers this time aspect of the data by controlling for time (i.e., survey wave) fixed effects wherever the time dimension is available. This implies that although it is not a panel, we account for common shocks that could have affected a country in a particular period. Additionally, to achieve this, we have merged each individual with the ECI index at the time they responded to the questionnaire (as we have values for ECI for the entire period). Therefore, we also capture the time-varying nature of ECI.

For the benchmark analysis (Table 1), we focus on the following five questions (in the parentheses we also report the code numbers of the answers i.e., the values of the respective variables adopted in our econometric specifications): Do you agree strongly (1), agree (2), disagree (3), or disagree strongly (4) with the statement: (i) 'A job is alright but what most women really want is a home and children'?; (ii) 'Having a job is the best way for a woman to be an independent person'?; (iii) "If a woman earns more money than her husband, it's almost certain to cause problems'?; (iv) 'Fathers are well suited for looking after children'?; and (v) Do you disapprove (0) or approve (1) 'abortion when the woman is not married'?

For the attitudes towards gender roles in the economy as a whole (Tables 2 and 3) we consider the questions: (i) Do you agree strongly (1), agree (2), disagree (3), or disagree strongly (4) with the statement 'When jobs are scarce, men should have more right to a job than women'?; (ii) Do you agree strongly (1), agree (2), disagree (3), or disagree strongly (4) with the statement 'On the whole, men make better political leaders than women do'?; (iii) Do you agree strongly (1), agree (2), disagree (3), or disagree strongly (4) with the statement 'On the whole, men make better business executives than women do'?; (iv) Many things may be

Table 3 ECI and gender norms in the public space- High GDP per Capita Countries (Threshold 60.000$).

	(1) Men should have more right to a job than women	(2) Men make better political leaders than women do	(3) Men make better business executives than women do	(4) Women have the same rights as men
ECI	−0.460*** (0.027)	−1.635*** (0.029)	−1.072*** (0.020)	−2.076*** (0.018)
ECI Squared	0.180** (0.019)	0.861*** (0.016)	0.514*** (0.017)	0.939*** (0.015)
Turning Point	1.27	0.94	1.04	1.10
Observations	4,992	4,023	2,982	2,990
R-squared	0.157	0.510	0.336	0.213

(i) The dependent variables take values: 0-1 (Column 1), 1–4 (Columns 2 and 3), 1–10 (Column 4). In all columns, lower values imply less favorable/more conservative attitudes towards women and higher values denote more favorable/modern attitudes towards women (see Table A5 in Appendix); (ii) All econometric specifications include individual and country controls (see in the text), country and wave/year fixed effects; (iii) Robust standard errors in parentheses; (iv) *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

desirable, but not all of them are essential characteristics of democracy. Please tell the following thing how essential you think it is as a characteristic of democracy. Use this scale where 1 means "not at all an essential characteristic of democracy" and 10 means it definitely is "an essential characteristic of democracy": 'Women have the same rights as men'.

For measuring the perceptions of individuals about features in women that are considered appreciable we use the questions: In your opinion, is it very important (1), somewhat important (2), neither important nor unimportant (3), little importance (4), no important at all (5) the following traits in a woman? (i) 'Wearing a veil in public places'; (ii) 'Being a good mother'; (iii) 'Being a good wife'; (iv) 'Being religious'; (v) 'Being educated'. All variables utilized in the analysis are described in Table A5 in the Appendix, while corresponding summary statistics are available in Table A6.

The analysis is conducted using a multi-level model in line with the Social Ecological Model (SEM). We utilize responses from individuals on the aforementioned questions obtained from the integrated version of the European Values Study and the World Values Survey (EVS/WVS). Additionally, we incorporate a comprehensive set of individual characteristics influencing attitudes towards women, such as gender, age (including age squared), income level, and educational attainment. However, limiting our analysis to the individual level overlooks significant determinants, such as country-level income (GDP) and openness to trade. To address this limitation, we augment the individual data with country-level controls. These controls encompass country and survey round fixed effects (comparable to time-fixed effects), as well as time-varying country-level variables that may impact cultural attitudes, including income per capita and the net volume of trade. The latter measure is particularly relevant considering the nature of the Economic Complexity Index (ECI).

In our benchmark specification, the multilevel model estimates the following specification:

$$GenderNorms_{ict} = \alpha_0 + \alpha_1 ECI_{ct} + \alpha_2 ECI_{ct}^2 + \alpha_3 X_i + \alpha_4 C_c + \alpha_5 FE_c + \alpha_6 R_t + \varepsilon_{ict}$$

$$(1)$$

where, $GenderNorms_{ict}$ represents the index of gender norms (derived from any of the four variables mentioned earlier) expressed by individual i, residing in country c, who participated in the t_th EVS/WVS round. ECI_{ct} denotes the level of the Economic Complexity Index (ECI) at the country level at time t, using lagged values. To address reverse causality concerns, albeit more challenging in a multi-level model, we associate each individual with past ECI values, considering them as predictors. We incorporate individual characteristics by including appropriate controls X_i, such as age, age squared, gender, education level, and income level. C_c represents a vector of additional country-level controls, including GDP per capita as a measure of development and the volume of trade as a proxy for openness. FE_c is a vector of country-fixed effects that control for all time-invariant unobserved heterogeneity at the country level. R_t is a vector of EVS/WVS fixed effects aimed at

capturing round-specific shocks that could affect individual responses. ε_{ict} denotes the error term. It is essential to note that while our outcome variables are either binary or ordered variables, we employ ordinary least squares (OLS) regressions in our benchmark specifications. This choice allows us to effectively introduce country and year fixed effects. Our multilevel analysis reveals that both cross-country controls and individual characteristics significantly influence attitudes towards gender roles, with economic complexity consistently correlating with them.

The economic complexity index. This paper primarily revolves around the Economic Complexity Index (ECI) sourced from MIT's Observatory of Economic Complexity. This index is derived from international trade data in the United Nations Comtrade database to assess the level of complexity in a country's economic structure. The methodology used for this purpose is known as the method of reflections (Hidalgo and Hausmann, 2009).

To be more specific, Hidalgo and Hausmann aim to capture the complexity of a nation's economic structure by taking into account two crucial aspects: the diversity of its economy, which is measured by the number of products it exports with a revealed comparative advantage (known as RCA), and the prevalence of its products in global markets, measured by the number of countries exporting a particular product with RCA. The underlying idea behind this approach is that complex economies demonstrate their ability to manufacture and export a wide range of advanced products with limited prevalence, a feat achieved only by a select group of countries with advanced production capabilities. In contrast, economies relying on less complex technologies have more limited production capabilities and, therefore, export a narrower range of commonly traded products. Machinery, chemicals, and metals are considered among the most sophisticated products, while raw materials, agricultural products, wood, and textiles are considered less sophisticated. As Hausmann and Hidalgo (2011) argue, quantifying productive capabilities, which encompass elements like infrastructure systems, the quality of human capital, institutional quality, and other non-tradeable production inputs, poses substantial challenges. Therefore, examining a country's export portfolio serves as a reliable means of extracting information about its productive capacity, a factor that plays a pivotal role in shaping future prosperity (Hausmann and Hidalgo, 2011; Hausmann et al. 2014).

The measures of **diversity** and **ubiquity** are computed as follows:

$$diversity = k_{c,o} = \sum_{p=1}^{Np} \left(M_{cp} \right)$$

$$ubiquity = k_{p,o} = \sum_{c=1}^{Nc} \left(M_{cp} \right)$$

where c and p stand for the country and product, respectively. M_{cp} equals one if country c exports product p with revealed comparative advantage, and zero otherwise.

This reflection approach involves a computational process that relies on the iterative calculation of an average value, considering the results from the previous iteration. As outlined by Hausmann and Hidalgo (2011) this iterative procedure commences with the assessment of diversity (denoted as $k_{c,0}$), which quantifies the number of products exported by a country each year. Subsequently, ubiquity (referred to as $k_{p,0}$) is introduced to consider information regarding the prevalence of these products in global markets. This aspect helps in ascertaining the number of products exported by a country while considering the prevalence or ubiquity of these products.

Furthermore, this iterative process also factors in the mean level of countries' diversity in exporting the same products as the focal country (denoted as country c). This iterative process continues until it reaches a point where no further useful information can be extracted from the preceding iteration.

In accordance with the framework established by Hausmann and Hidalgo (2011), the nth iteration can be expressed as follows:

$$k_{c,n} = \frac{1}{k_{c,o}} \sum_{p=1}^{Np} \left(M_{cp} k_{p,n-1} \right)$$

where

$$k_{p,n-1} = \frac{1}{k_{p,o}} \sum_{c=1}^{Nc} \left(M_{cp} k_{c,n-2} \right)$$

Substituting $k_{p,n-1}$ into $k_{c,n}$, we obtain

$$k_{c,n} = \frac{1}{k_{c,o}} \sum_{p=1}^{Np} \left(M_{cp} \frac{1}{k_{p,o}} \right) \sum_{c'=1}^{Nc'} \left(M_{c'p} k_{c',n-2} \right)$$

We can re-express it as follows (Yellen, 2020):

$$k_{c,n} = \sum_{c^1=1} \widetilde{M}_{cc'} k_{c',n-2}$$

where

$$\widetilde{M}_{cc'} = \sum_p \frac{M_{cp} M_{c'p}}{k_{c,o} k_{p,o}}$$

Finally, the Economic Complexity Index is given by

$$ECI_c = \frac{\vec{K} - \langle \vec{K} \rangle}{std(\vec{K})}$$

in which $\vec{K}$ is the eigenvector of $\widetilde{M}cc'$ associated with the second largest eigenvalue, $\langle \cdot \rangle$ and std are the average and standard deviation, respectively.

Results

Table 1 summarizes our main findings. For contexts characterized by low levels of economic complexity, a higher Economic Complexity Index (ECI) is associated with the following: (i) A greater likelihood to agree with the statement "*A job is all right, but what most women really want is a home and children*" (see column 1). (ii) A greater likelihood to disagree with the statement "*Having a job is the best way for a woman to be an independent person*", indicating a weaker attitude towards women's independence through work (see column 2). (iii) A lower likelihood to agree with the statement "*If a woman earns more money than her husband, it's almost certain to cause problems*" (see column 3). (iv) A greater likelihood to disagree with the statement "*Fathers are well suited for looking after children*" (see column 4). (v) A higher likelihood to approve of "*Abortion when the woman is not married*" (see column 5).

However, a specific threshold of economic complexity is associated with a shift in norms—a Turning Point. Beyond this threshold of Economic Complexity Index (ECI) (refer to the

values of the Turning Point in Table 1 for each dependent variable/column), a higher ECI is linked with less rigid gender norms. Particularly, within the range of ECI values above the Turning Point, increased economic complexity correlates with overall less rigid gender norms.

Furthermore, beyond the Turning Point, there is an increased likelihood of encountering attitudes that view fathers as suited to raise children, as well as attitudes towards unmarried women with children. It is noteworthy that all levels of turning points presented in Table 1 are within the range of ECI values observed in our sample, which has an average of 0.382 and a standard deviation of 0.773 (refer to Table A2).

In addition, we also explore whether ECI is associated with gender norms that concern women in the public sphere. Results are shown in Table 2.

A higher level of the Economic Complexity Index (ECI) is not directly associated with gender norms regarding the role of women in society. However, as illustrated in Table 3, when focusing on countries with a relatively high level of income, further growth in ECI becomes pertinent in shaping views about female emancipation in societal roles. Taken all together, our findings indicate that ECI is initially associated with gender norms concerning women and men within the household. Subsequently, with higher levels of ECI, the relationship between gender norms and economic complexity transitions towards gender norms pertaining to women in the public sphere.

For illustrative purposes only, Fig. 2 presents the unconditional correlation between the Economic Complexity Index (ECI) and the five gender norms. We depict country-level averages across all waves. Interestingly, we observe significant heterogeneity across countries and attitudes. It is important to note that our entire analysis is conducted at the individual level using a multilevel model. The formalized results, derived from the multilevel analysis using individual-level data, are presented in the empirical analysis conducted above, specifically in Tables 1–3.

Discussion

The central idea of this study is that economic complexity is related to gender norms. Interestingly, this relationship is not linear, and it is strong primarily for gender norms in the family. Only if the economic conditions are quite favorable (GDP per capita, higher than 60,000 $), then the link between ECI and gender norms for women in the public sphere appears.

Results presented in Table 1 indicate that the Turning Point varies significantly across different gender norms. For instance, in Column 4 (Fathers as child carers), a much higher level of economic complexity is required to reach the Turning Point. This finding aligns with the notion that a substantial stock of knowledge accumulation is necessary for further increases in economic complexity to be associated with less rigid gender norms favoring the 'caring male role'. Sear (2021) and van Poppel et al. (2009) have challenged the notion of the male breadwinner nuclear family as a universally traditional family structure. This literature highlights the dependency of this family model on specific economic conditions, such as increased agricultural productivity and industrialization. Indeed, the role of fathers in direct childcare varies across different hunter-gatherer societies, indicating cultural diversity in gender roles.

Analyzing our data from 2010, countries can be classified into four groups based on their ECI levels. Some countries, such as France, Germany, Switzerland, Japan, and the USA, have an ECI beyond the Turning Point in all attitudes in Table 1, implying that further economic complexity is undeniably associated with less rigid gender norms in the household in
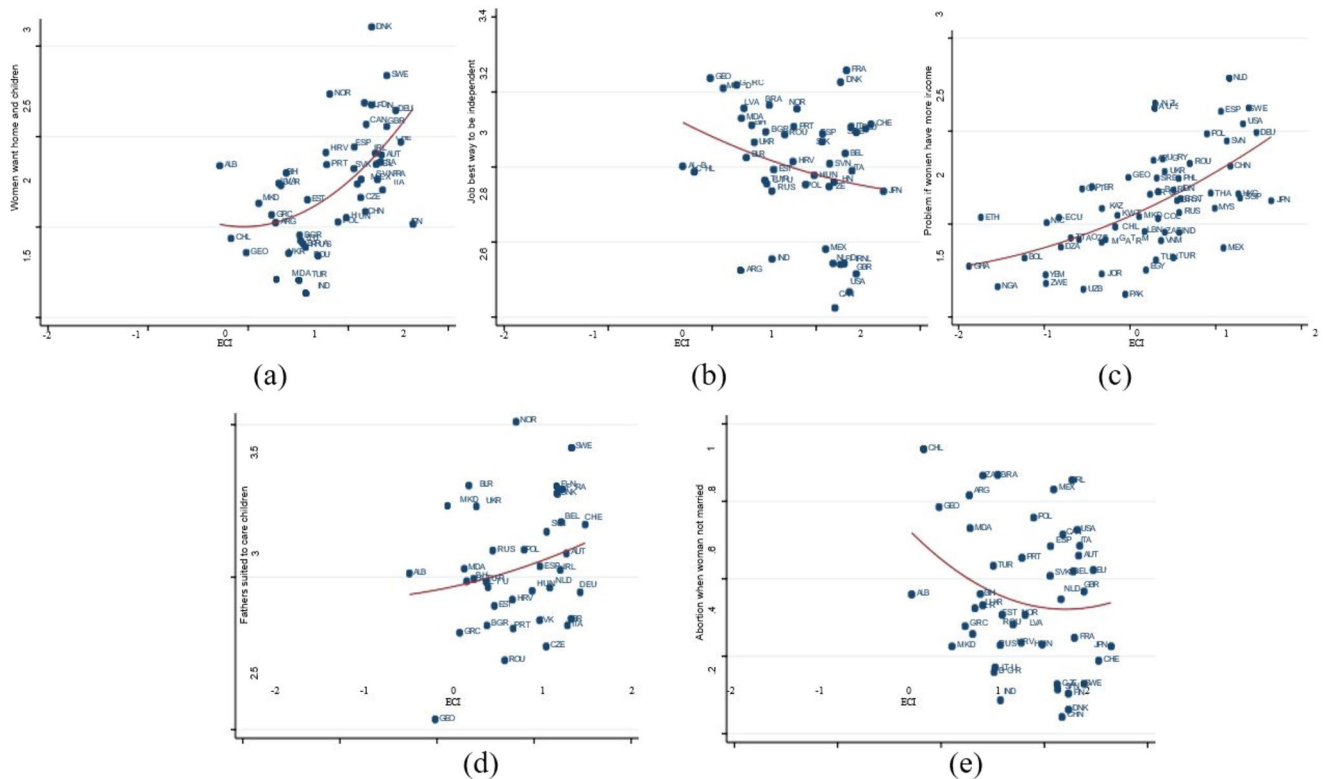
Fig. 2 ECI and gender norms. ECI vs mean values of responses on whether individuals agree with the following statements **a** *A job is all right but what most women really want is a home and children,* **b** *Having a job is the best way for a woman to be an independent person,* **c** *If a woman earns more money than her husband, it's almost certain to cause problems,* **d** *Fathers are well suited for looking after children,* **e** *Abortion when the woman is not married.* The answers for questions **a** and **c** take values from 1–4 and are scaled as follows: *Do you agree strongly (1), agree (2), disagree (3), or disagree strongly (4)* with each statement? The scale is reversed for questions **b** and **d**. Question **e** takes values 0 (approve)-1 (disapprove). Please note that the graphs rely on the original scale of the World Values Survey (WVS). In Table 1-A2 though the scales have been harmonized to facilitate the interpretation of the results and the comparability. The vertical axes are thus illustrating the mean values of each of the above norms for all waves/per country. The horizontal axis illustrates the mean value of ECI at the country level.

these countries. Others, like Spain, Denmark, Finland, Hong Kong, and Israel, have an ECI exceeding the Turning Point in some columns but not yet in others, indicating that additional improvement in ECI is needed for a relationship to emerge between ECI and certain gender norms. Conversely, countries like Argentina, Brazil, Egypt, Canada, Greece, India, Portugal, and Turkey have an ECI exceeding the Turning Point only in certain columns, suggesting that further increases in economic complexity are temporarily associated with rigid gender norms in those areas.

To provide context, the mean value of ECI in our sample corresponds to the level of complexity observed in economies like Canada around the year 2015 or Hong Kong around the period 1997–1999. For instance, the turning point for the sample corresponding to Column 3 of Table 1 ("If a woman earns more money than her husband, it's almost certain to cause problems") is approximately 0.225, which is akin to the level of complexity experienced by Argentina around the year 2010.

Figure 3 illustrates hypothetically what could occur if a country like Argentina, close to the Turning Point, were to experience a significant reduction or increase in ECI. Such changes, while holding other factors constant, could be associated with shifts towards more rigid or less rigid gender norms, respectively. However, it's essential to note that this is a conceptual exercise, and the results are subject to causality constraints. Tables A7 and A8 provide a closer examination of countries near the turning point for each column of the benchmark analysis.

The underlying mechanisms. Our hypothesis regarding the association between the knowledge embedded in an economy's productive structure and cultural norms contributes to the broader literature on the economic determinants of culture. However, we introduce a novel element by focusing on economic complexity. Why might economic complexity correlate with gender roles? We posit that two underlying forces are at play, with varying significance across the decreasing and increasing segments of the U-shaped relationship between the Economic Complexity Index (ECI) and gender norms.

Firstly, the adoption of advanced technologies supports the notion that economic opportunities for men and women in the labor market may be similar. Consequently, the division of labor within the family becomes more flexible, with both fathers and mothers capable of caregiving and participating in the workforce. A complementary second-order channel operates through the person-byte effect. Individuals possessing high levels of human capital necessary for producing sophisticated products are likely to reside in countries with high economic complexity. This heightened human capital further reinforces norms advocating for gender equality, as individuals with such capital are more inclined to perceive and believe in the changing economic prospects of women in both household and work settings.

Analytically, we argue that the process of knowledge accumulation intricately links to women's economic prospects in the labor market and, consequently, how women are perceived. The dynamic nature of evolving technologies and increasing economic complexity influences women's productivity in the labor market, aligning it
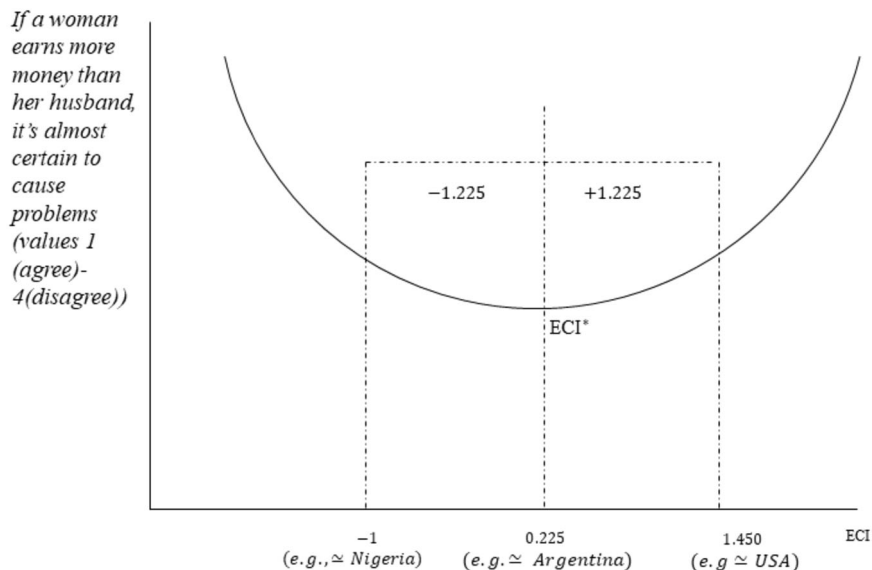
Fig. 3 Illustration of the *Turning Point* with examples for the question "*If a woman earns more money than her husband, it's almost certain to cause problems*" (Column 3 of Table 1).

more closely with that of men. As a result, women become stronger economic agents, which gradually reshapes perceptions of gender roles within family structures, markets, and society. Drawing from Becker's rationale (Becker, 1973), women traditionally assume the role of housewives due to their lower labor market productivity and wages compared to the benefits they contribute to the family as homemakers. However, as economic complexity shifts the balance of labor market productivity within the family, this can lead to changes in gender roles at home and in society.

There are several ways in which the process of knowledge accumulation is correlated with the development of less rigid norms. Firstly, knowledge accumulation often entails exposure to a diverse array of information, ideas, and perspectives. In complex economies, individuals frequently encounter a broad spectrum of role models and societal norms, including those related to gender. This exposure has the potential to challenge gender stereotypes and broaden one's understanding of gender roles (Kabeer, 2000; Klasen and Lamanna, 2009). Secondly, knowledge accumulation is closely linked to education and learning. In nations with high economic complexity, educational systems, and awareness programs may actively promote gender equality and question traditional gender norms. Furthermore, technological advancements and economic complexity often correlate with increased access to information and media. Individuals in such societies are more likely to be exposed to information regarding gender equality, women's rights, and evolving gender dynamics through various channels such as the Internet, television, and print media (UN Women, 2023). Lastly, social interactions and peer influences may play a pivotal role. People interact with peers who may hold progressive views on gender roles, leading to meaningful discussions and exchanges of ideas that contribute to shifts in beliefs and more adaptable gender role choices (Bertrand and Mullainathan, 2003). Based on the aforementioned points, it is reasonable to suggest that one potential implication of our findings is that knowledge accumulation might signify a broader process of societal change, eventually reflected in evolving beliefs and norms. Our chosen outcome variable serves as a proxy for measuring these traits, capturing individuals' beliefs at a specific point in time. Additionally, given that our samples are representative in terms of sample selection, they provide insight into a country's average beliefs at a given point in time.

In the decreasing phase of the U-shaped pattern, as economies transition from lower to moderate levels of economic complexity, there may indeed be a period where gender norms become more entrenched. Firstly, this could be attributed to various factors such as initial resistance to change, cultural inertia, and the fact that not all aspects of knowledge evolve at the same pace. During this phase, technological advancements might initially favor men in the labor market, thus reinforcing traditional gender roles. Secondly, while technological advancements might eventually lead to greater gender equality, initially, the association with these advancements could be selective, favoring certain sectors or industries traditionally dominated by men. This selective association means that knowledge accumulation reflects a rational assessment of the changing economic prospects of men and women in the economy. For example, in the early phases of industrialization, industries dominated by men might experience growth, thereby solidifying gender norms that exclude women from the industrial labor market. Thirdly, societal attitudes often lag behind economic and technological changes. Even as the economy becomes more complex, cultural norms might take time to catch up. This lag could explain why, in the decreasing phase, gender norms temporarily become more rigid before eventually evolving.

Lastly, historical evidence often demonstrates that in the early stages of industrialization, gender roles sometimes become more pronounced before undergoing significant transformations. This historical precedent can help elucidate the decreasing phase. It should be highlighted, however, that our study does not definitively establish a causal awareness mechanism underlying these shifts in gender attitudes.

In empirically exploring elements of our mechanism, we employ measures that implicitly capture individuals' perceptions regarding attributes deemed desirable in women. Specifically, we investigate the relationship between Economic Complexity Index (ECI) and various traits associated with women, such as education, motherhood, spousal roles, religiosity, and veiling practices. As presented in Table 4, the coefficient of ECI exhibits significant strength (linear term), and the rate of change is also increasing (quadratic term). This suggests that as ECI increases, attributes such as education, being a good mother, or being a good wife become more attractive, while the appeal of religiousness or wearing a veil diminishes. These findings underscore a

Table 4 Channels: The link between ECI and the Appreciable Traits for Women.

	(1)	(2)	(3)	(4)	(5)
	Traits in a woman:				
	wearing veil	**good mother**	**good wife**	**religious**	**educated**
ECI	9.456*** (0.190)	−0.531*** (0.032)	−0.506*** (0.042)	1.369*** (0.196)	−0.353*** (0.048)
ECI Squared	4.523*** (0.096)	−0.248*** (0.026)	−0.267*** (0.034)	1.113*** (0.151)	−0.052 (0.038)
Observations	12,572	15,169	15,163	15,153	15,145
R-squared	0.543	0.039	0.035	0.122	0.119

(i) The main outcome variables take values from 1 ("Very important") to 5 ("No important at all"); (ii) All econometric specifications include individual and country controls (see in the text), country and wave/year fixed effects; (iii) Robust standard errors in parentheses; (iv) *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

correlation wherein economic complexity is linked with a shift in the range of traits deemed desirable for women, ultimately aligning with the emergence of more egalitarian gender attitudes.

It is noteworthy that, concerning other control variables, we observe an intriguing trend wherein globalization is correlated with more flexible gender roles. However, the sign of the GDP per capita is predominantly negative. This aligns with prior seminal work by Goldin ([1995]). Importantly, our findings regarding the effects of economic complexity persist even after controlling for GDP per capita.

Limitations. While our research unveils a novel association between economic complexity and cultural shifts in gender roles, it is important to acknowledge several limitations that warrant attention in future studies. The main constraint of the paper is that, despite accounting for a large number of unobservables through various types of fixed effects, as well as individual and country-level controls, and utilizing a multilevel model to address concerns regarding reverse causality, definitively claiming a causal effect remains challenging. Throughout the paper, we emphasize that our findings primarily indicate correlations among the variables of interest. In other words, our results suggest that the Economic Complexity Index (ECI) is associated with these norms. However, we cannot assert with full certainty that ECI causes these norms to exist, although we speculate on underlying mechanisms that could operate in this manner. In this regard, having access to a longitudinal dataset that tracks the same individuals over time would be helpful in further exploring this direction.

Additionally, in line with the first argument, we hypothesize that one of the underlying channels linking economic complexity with gender norms is human capital accumulation. This hypothesis is grounded in the literature on ECI, which underscores the role of human capital and its association with the index. Nonetheless, there may be other mechanisms at play that connect economic complexity with gender norms. This study primarily focuses on the reduced form effect of ECI on gender norms and does not empirically pinpoint the associated mechanism. Thus, comprehensively understanding the complex dynamics that link the two remains a challenge ahead of us.

Conclusion

This paper has explored the intricate relationship between economic complexity, knowledge accumulation, and gender norms. Through a comprehensive analysis utilizing data from up to 49 countries and considering the attitudes of over 64,000 individuals, we have uncovered significant insights into how economic development influences cultural perceptions of gender roles.

Our findings indicate a non-linear relationship between economic complexity and gender norms within the household, characterized by a U-shaped function. In societies with limited

economic complexity, further increases in economic complexity are associated with more rigid gender norms. However, as economic complexity reaches higher levels, additional increases correlate with less rigid gender norms, particularly regarding women's roles within households. This suggests that the initial stages of knowledge accumulation may coincide with the reinforcement of traditional gender roles, especially concerning women's domestic responsibilities. However, as economies become more complex, with advancements in technology and education, gender norms within households tend to become more flexible, allowing for greater gender equality in domestic roles.

Moreover, our analysis highlights the association between economic complexity and gender norms in the public sphere. While economic complexity is linked with attitudes towards women's leadership, business executive roles, and participation in politics, this association becomes significant primarily in countries with relatively high income per capita. This suggests that economic sophistication is necessary for significant changes in gender norms pertaining to women's public roles to manifest.

These findings underscore the importance of considering socioeconomic factors in understanding the evolution of gender norms. Economic development, as reflected in economic complexity, plays a pivotal role in shaping cultural perceptions of gender roles, both within households and in the public sphere. Our study contributes to the existing literature by providing empirical evidence of the interplay between economic complexity and gender norms, shedding light on the mechanisms driving societal change.

For policymakers and stakeholders, these insights offer valuable guidance in promoting gender equality initiatives within the context of economic development. Recognizing the influence of economic complexity on cultural attitudes towards gender roles can inform strategies aimed at fostering more inclusive and equitable societies. By addressing the underlying socioeconomic factors that shape gender norms, policymakers can work towards creating environments that support the advancement of gender equality across various domains of society.

Data availability

Datasets generated during and/or analyzed during the current study are available at the following link: https://doi.org/10.7910/DVN/ZKJ1VD.

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Author contributions

All authors, AL, AL and SZ have contributed equally to this work. AL, AL and SZ collectively conceived and designed the study, conducted data collection and analysis, and wrote the manuscript. AL, AL and SZ participated in critical discussions regarding the interpretation of results and provided substantial revisions to the manuscript. AL, AL and SZ have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

Informed consent was not required as the study did not involve human participants.

Additional information

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