

THE OUTPUT COST OF GENDER DISCRIMINATION: A MODEL-BASED MACROECONOMICS ESTIMATE*

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We use a growth model in which saving, fertility and labour market participation are endogenous, to quantify the cost that barriers to female labour force participation impose in terms of an economy's output. The model is calibrated to mimic the US economy's behaviour in the long-run. We find that a 50% increase in the gender wage gap leads to a 35% decrease in income *per capita* in the steady state. Using independent estimates of the female to male earnings ratio for a wide cross-section of countries, we construct an economy with parameters similar to those calibrated for the US economy, except for the degree of gender barriers. For several countries, a large fraction of the difference between the country's output and the US output can be ascribed to differences in gender discrimination.

Everywhere females find it more difficult than males to access market activities, political power, or health and education inputs.¹ Hausmann *et al.* (2006) suggest that 'no country in the world has yet reached equality between women and men in critical areas such as economic participation, education, health and political empowerment' (pp. 18).² Gender discrimination has many guises, probably interrelated in their causes and consequences, as they are part of a complex system of social, cultural and economic determinants. The economics literature has studied the microeconomics of job and wage discrimination in some detail, thus far focusing on the individual cost of discrimination.³ We believe it is time to estimate the aggregate cost of gender discrimination, and for that purpose, we use a long-run macromodel where discrimination affects investment, fertility, and the steady-state features of the economy.

Providing an estimate of the cost of discrimination to aggregate output is important for several reasons. First, gender inequality remains high in many

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¹ As an example, Alesina *et al.* (2013) show that Italian women have to pay higher interest rates than men, even when exhibiting a better credit history, and after controlling for a host of personal and firm characteristics.

² See also the 2012 World Development Report (World Bank, 2011) on gender equality and development.

³ Some authors have argued that the tax rates on second earners (usually the woman) are much higher than those on the first earner, *de facto* further discouraging female labour force participation (Bick and Fuchs-Schündeln, 2012). Alesina *et al.* (2011) have suggested going further and imposing differential gender-based tax rates, especially given the higher tax elasticity of women's labour supply.

countries (Hausmann *et al.*, 2006; Doepke *et al.*, 2012). Second, although gender discrimination is largely determined by social and cultural characteristics which hardly change in the short run,⁴ there are several gender-related policies which could foster gender equality and therefore reduce discrimination.⁵ Finally, to our knowledge, this is the first article to use a structural model to quantify the long-run output effects of barriers to female labour force participation. A model-based estimate is key as it takes into consideration how agents and prices respond to different levels of gender discrimination. Such a model also captures indirect effects of gender discrimination, including endogenous changes in the fertility rate, while allowing us to run counterfactual experiments that take into account general equilibrium effects.

From the seminal paper by Galor and Weil (1996), a strand of the literature has examined gender-related issues within a growth framework.⁶ An example is Lagerlöf (2003) who focuses on the relationship between gender discrimination and long-run growth. His model of a secular economy inspired on the European historical experience, relates gender discrimination with the industrial revolution and the demographic transition.⁷ Doepke and Tertilt (2009) develop a model to explain how women's economic and legal rights are endogenously extended over the process of economic development.⁸ We build our model based on this literature but we study a different question, which is how gender discrimination quantitatively impacts the economy over the development process. In our model, gender discrimination drives a wedge between women's labour productivity and female wages. We calibrate the model economy so that the long-run equilibrium matches key statistics of the US economy, including the gender wage gap. We then explore how the equilibrium properties of the model change with the level of gender discrimination. This counterfactual exercise provides an estimate of US output *per capita* and fertility when the gender wage gap is the same as in, for instance, Egypt. The effect of gender discrimination on the economy depends on two forces: less discrimination increases market activity by women, which directly increases output *per capita*; it also reduces fertility and increases capital accumulation and thus long-

⁴ See Fernandez (2007) and Algan and Cahuc (2007) for the importance of culture and family characteristics on FLFP. For the role of religion on FLFP, see Psacharopoulos and Tzannatos (1989), Siaroff (1994) and Guiso *et al.* (2003). Fernández *et al.* (2004) show that men whose mothers worked while they were growing up tend to marry working women. See also Acemoglu *et al.* (2004).

⁵ For instance, improvement in women's legal rights, and female empowerment through gender-related education and training programmes. See Doepke *et al.* (2012) for a documentation of how women's rights vary across countries.

⁶ There is a related literature which studies empirically the effects of gender inequality on human capital accumulation and economic development and economic growth (Dollar and Gatti, 1999; Seguino, 2000; Hausmann *et al.*, 2006; Daly, 2007). Using growth accounting exercises, Young (1995) found that the rise in female labour force participation accounted for between 0.6 and 1.6% of annual *per capita* growth in the four East Asian tiger economies. Our research is complementary to this literature since we provide a structural estimation instead of a reduced form estimation.

⁷ See also Greenwood *et al.* (2005*b*) who investigate the role of innovation in home appliances on fertility and female labour force participation.

⁸ See also Hazan and Maoz (2002), who show how social norms regarding women's labour force participation change over time. Bertocchi (2011) offers a rationale for the decision to extend the franchise to females, emerging from within a politico-economic model. The driving force in her analysis is the increase in the return for intellectual labour relative to physical labour.

run equilibrium *per capita* output. We show how, for some countries, a very large fraction of the difference between the country's output and US output is explained by differences in gender discrimination. We also provide an extension of the model in which the wedge between women's productivity and their wage decreases with capital accumulation. Our results are robust to this extension.

As to the nature of the exercise, the study most directly related to ours is Hsieh *et al.* (2012), who investigate the aggregate productivity gains in the US, between 1960 and 2008, which can be attributed to decreases in labour market discrimination towards African-Americans and women. While their paper focuses on the aggregate costs of labour market discrimination on occupational allocations in the US, we take the US economy as our benchmark and then compute the costs of gender discrimination in the labour market for a cross section of countries, given endogenous savings and fertility rates.

The article proceeds as follows. Section 1 presents the model, describes the behaviour of each agent in the economy and defines the equilibrium. Section 2 derives some analytical results using a simplified version of the model, which is useful to provide the intuition behind our quantitative exercises. Section 3 describes the model calibration and contains simulations designed to evaluate the effects of gender discrimination on the benchmark economy. It also considers a model extension in which the wedge between women's productivity and their wage changes with capital accumulation. Finally, Section 4 contains concluding remarks.⁹

1. The Model

In this Section, we develop a model to study the cost of gender discrimination to output. Our strategy is to use a simple growth model with endogenous fertility and female labour market participation to assess the costs of gender discrimination.

1.1. *Women and Men*

Our economy is made up of men and women who live for three periods. In the first period, as children, women and men are indistinguishable, do not make any specific decision, and 'consume' a fraction of their parents' time endowment, our proxy for parental care. In their second period of life, agents become adult men and women, organised as couples, and differ in their productivity in raising children. We assume that women are more productive than men in raising children but they are equally productive in market activities. Both men and women can use one unit of time, divided between time at work and time raising children. During this second period of life, couples decide how many children to have and allocate their time between the labour market and the task of raising children. In the third period, each couple consumes the life savings.

The novelty relative to macroeconomic models of fertility and labour market participation is the introduction of gender discrimination. We assume that there are

⁹ There are also online Appendices with some robustness exercises.

barriers to female labour market participation in the form of wage discrimination. If we take w_t to be the labour wage rate, women receive the fraction $\phi < 1$ of this wage rate, so a lower ϕ represents a more discriminatory society.¹⁰ Therefore, ϕ corresponds to a wedge faced by women between their labour productivity and their wage.¹¹ Therefore, it acts as a distortionary tax and hence generates some type of inefficiency (misallocation) in the economy. It can be due to direct discrimination (preference-based discrimination as in Becker (1957)) and restricted job's opportunity, such as glass ceiling. We do not explicitly model how gender discrimination maps into different values for ϕ , a task conducted in Fernández *et al.* (2004), Doepke and Tertilt (2011) and Rahim and Tavares (2012), who take gender discrimination in the labour market as endogenous. Discrimination costs are redistributed back to households in a non-distortionary, lump-sum manner such that, in our model, the cost that discrimination generates is solely the wedge between women's wage and their marginal productivity.¹² Giving micro-foundations for ϕ is clearly an important extension but it goes beyond the goal of this article, which is to measure whether or not barriers to female labour force participation might have sizeable quantitative effects on output *per capita* and what the channels are. A similar approach is taken by Parente and Prescott (1994) and Hall and Jones (1999), who quantify how differences in total factor productivity (TFP) explain differences in output per worker in the long run; or by Restuccia and Rogerson (2008), Guner *et al.* (2008) and Hsieh and Klenow (2009), who quantify the effects of input misallocation on productivity in different countries.

1.2. Technology

The production technology uses capital, K_t , and labour, L_t , to produce output, Y_t , according to a constant returns to scale production function. More specifically,

$$Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}, \quad (1)$$

where $A_t = (1 + \mu)^t$, and $\alpha \in (0,1)$. Parameter $\mu \geq 0$ corresponds to the rate of technical progress. Given the technology and input prices, the representative firm chooses inputs so that profits are maximised.¹³ Let w_t be the wage rate and r_t^K denote the rental rate of capital. The first-order conditions associated with the representative firm's problem are as follows:

$$w_t = (1 - \alpha) K_t^\alpha (A_t L_t)^{-\alpha} A_t, \quad (2)$$

¹⁰ A similar approach is used by Jones *et al.* (2003) and Hsieh *et al.* (2012), who argue that the narrowing wage gap alone explains a large part of the recent increase in female labour force participation in the US. Lagerlöf (2003), instead, sets up a growth model in which gender differences arise endogenously in equilibrium through a coordination process. Related to this article is the model presented by Soares and Falcão (2008) in which increases in female labour force participation and reductions in the gender wage gap are the output of reductions in fertility and in mortality rates.

¹¹ Here we assume that ϕ is fixed. In subsection 3.4, we let ϕ change with capital accumulation. This is indeed a more realistic assumption. However, the approach of an exogenous ϕ simplifies the analysis and the proof of existence of a balanced growth path equilibrium.

¹² This is immaterial for the qualitative nature of the results in our model. In addition, our quantitative analysis will provide conservative measures of the output costs of discrimination.

¹³ Output is taken as the numeraire.

$$r_t^K = \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha}. \quad (3)$$

1.3. Preferences

As suggested above, couples draw utility from consumption in their second and third period of life, and from the number of children. Let n_t be the number of children born at period t ,¹⁴ and c_t and d_{t+1} be the consumption of a couple in their second and third period of life, respectively. Preferences are represented by

$$U_t = \ln(c_t + \bar{c}_t) + \beta \ln d_{t+1} + \gamma \ln n_t, \quad \beta, \gamma \in (0, 1), \quad (4)$$

where β is the subjective discount factor and γ represents the relative weight of children in the couple's utility function. Quantity \bar{c}_t corresponds to home produced consumption goods. As in Greenwood *et al.* (2005a), \bar{c}_t generates a decline in fertility as the economy develops. See Hazan and Berdugo (2002) for a similar approach. We assume that home production increases with technical change, such that $\bar{c}_t = A_t \bar{c}$, where $\bar{c} > 0$.¹⁵

Let h_t^w and h_t^h denote the time of the wife and the husband spent in raising children. In the spirit of Greenwood *et al.* (2005a), we assume that children consume time resources according to the equation

$$n_t = D(h_t^w + \eta h_t^h)^\theta, \quad D > 0, \theta \in (0, 1). \quad (5)$$

Parameters $D > 0$ and $\theta > 0$ determine the level and curvature, respectively, of the production function to raise children. We assume that $\eta \in (0, 1)$, which implies that women are more productive than men in raising children, as emphasised by Albanesi and Olivetti (2009) in relation to women's ability to breastfeed.¹⁶

1.4. Budget Constraints

The couple's budget constraints are as follows:

$$c_t + s_t \leq w_t(1 - h_t^h) + \phi w_t(1 - h_t^w) + \varpi_t, \quad (6)$$

$$d_{t+1} \leq (1 + r_{t+1})s_t, \quad (7)$$

where s_t represents investment and the right-hand side shows net income of the couple. Variable ϖ_t stands for transfers to households. We assume that discrimination costs are redistributed in lump-sum back to households. This implies that the cost of discrimination we calculate is only due to a wedge between women's marginal productivity of labour and their wage. In other words, the effect is due to misallocation and distortionary discrimination, not due to any waste of resources.

¹⁴ Since the household is organised as a couple, we could interpret n_t as the number of couples generated by each household.

¹⁵ Therefore, there is technical change in home production, as suggested by Greenwood *et al.* (2005b) and Cavalcanti and Tavares (2008). In addition, this generates a long-run balanced growth path equilibrium in which per worker capital and output grow at the rate of technical change.

¹⁶ In online Appendix A, we present a model based on Galor and Weil (1996) in which there are two types of labour, mental and physical labour, where, for each unit of time, men have a higher endowment of physical labour than women but an equal endowment of mental labour. Quantitative results are similar using both approaches.

Couples choose the level of consumption when young, c_t , and when old, d_{t+1} , the number of children n_t , the fraction of time allocated to household chores h_t^w and h_t^h , and savings, s_t , all this so as to maximise (4) subject to (5), (6), and (7). It can be shown that when $h_t^w < 1$ then $h_t^h = 0$,¹⁷ and

$$h_t^w = \frac{\gamma\theta}{(1 + \beta + \gamma\theta)} \left(\frac{1 + \phi}{\phi} + \frac{\bar{c}_t}{\phi w_t} + \frac{\varpi_t}{\phi w_t} \right), \quad (8)$$

which is increasing in gender inequality (lower ϕ). When $h_t^w < 1$ then $h_t^h = 0$, then consumption and investment are as follows:

$$c_t = \frac{1}{1 + \beta + \gamma\theta} [(1 + \phi)w_t - (\gamma\theta + \beta)\bar{c}_t + \omega_t], \quad (9)$$

$$s_t = \frac{\beta}{1 + \beta + \gamma\theta} [(1 + \phi)w_t + \bar{c}_t + \omega_t], \quad (10)$$

$$d_{t+1} = (1 + r_{t+1})s_t. \quad (11)$$

But it can be the case that $h_t^w = 1$ and $h_t^h \in (0, 1)$. Then, we have:

$$h_t^h = \frac{\gamma\theta}{(1 + \beta + \gamma\theta)} \left(\frac{1 + \eta}{\eta} + \frac{\bar{c}_t}{w_t} + \frac{\varpi_t}{w_t} \right) - \frac{1}{\eta}. \quad (12)$$

If η is sufficiently small ($\eta \rightarrow 0$), then $h_t^h = 0$ for any finite wage. We make this assumption here and investigate the model in which $h_t^h = 0$ and $h_t^w \in (0, 1]$.

1.5. *Equilibrium*

Let P_t denote the number of adult households in period t . In equilibrium, demand equals supply in all markets. In the labour market this means that $L_t = P_t(2 - h_t^w)$. Let \hat{k}_t be the capital level per unit of efficiency couple, that is, $\hat{k}_t = K_t/A_tP_t$. We also have $\varpi_t = (1 - \phi)(1 - h_t^w)w_t$, which corresponds to the resources firms lose because they discriminate. Transfers are equal to the cost of discrimination. Then, using (2) into (8), yields:

$$h_t^w = \min \left\{ 1, \frac{\gamma\theta}{(1 + \beta)\phi + \gamma\theta} \left[2 + \frac{\bar{c}}{(1 - \alpha)\hat{k}_t^\alpha (2 - h_t^w)^{-\alpha}} \right] \right\}. \quad (13)$$

From the expression above, a necessary condition for women to participate in the labour market is that:

$$\text{ASSUMPTION 1. } \frac{2\gamma\theta}{(1 + \beta)\phi + \gamma\theta} \leq 1 \Rightarrow \phi \geq \frac{\gamma\theta}{1 + \beta}.$$

¹⁷ Observe that, for $h_t^w < 1$ and $h_t^h > 0$ we would need $\eta \geq 1/\phi$, which cannot ever be the case since $\phi < 1$ and $\eta < 1$.

Assumption 1 implies a limit for the size of gender discrimination in the labour market. We have

$$n_t = D \left(\min \left\{ 1, \frac{\gamma\theta}{(1 + \beta)\phi + \gamma\theta} \left[2 + \frac{\bar{c}}{(1 - \alpha)\hat{k}_t^\alpha(2 - h_t^w)^{-\alpha}} \right] \right\} \right)^\theta, \tag{14}$$

and the following Proposition holds:

PROPOSITION 1. *Let Assumption 1 be satisfied so that women participate in the labour market. Then we have:*

- (i) *female hours of work in the market increase with capital accumulation, \hat{k}_t , and decrease with labour market discrimination (low ϕ); and*
- (ii) *fertility decreases with capital accumulation, \hat{k}_t , and increases with labour market discrimination (low ϕ).*

Proof. Equation (13) determines h_t^w as an implicit function of \hat{k}_t , $\psi(\hat{k}_t, \phi)$, and a critical value $\hat{k}^*(\phi)$ such that

$$h_t^w = \begin{cases} 1 & \text{for } \hat{k}_t \leq \hat{k}^*(\phi), \\ \psi(\hat{k}_t, \phi) & \text{for } \hat{k}_t \geq \hat{k}^*(\phi), \end{cases} \tag{15}$$

and $\psi(\hat{k}_t, \phi) \in (0, 1] \forall \hat{k}_t \geq \hat{k}^*(\phi)$, where:

$$\hat{k}^*(\phi) = \left\{ \frac{\bar{c}\gamma\theta}{(1 - \alpha)[\phi(1 + \beta) - \gamma\theta]} \right\}^{\frac{1}{\alpha}}. \tag{16}$$

Using the implicit function theorem we can show that $\psi_1(\hat{k}_t, \phi) < 0$ and $\psi_2(\hat{k}_t, \phi) < 0$, as long as $\hat{k}_t \geq \hat{k}^*(\phi)$. The second part of the proof is trivial since $n_t = D(h_t^w)^\theta$ and $D > 0$ and $\theta > 0$.

Proposition 1 implies that time devoted to home activities decreases with capital accumulation. Observe that when barriers to female labour force participation are high (ϕ is low), women work fewer hours in the market. Since fertility is an increasing function of hours at home, the number of children decreases with capital accumulation and increases with gender discrimination in the form of barriers to female labour force participation.

In equilibrium, we have that savings are given by the following:

$$s_t = \begin{cases} \frac{\beta}{1 + \beta}(w_t + \bar{c}_t) & \text{for } h_t^w = 1, \\ \frac{\phi\beta}{(1 + \beta)\phi + \gamma\theta}(2w_t + \bar{c}_t) & \text{for } h_t^w < 1. \end{cases} \tag{17}$$

The condition that equilibrates the capital market is

$$K_{t+1} = P_t s_t. \tag{18}$$

Since $P_{t+1} = n_t P_t$, capital per effective unit of workers is

$$\hat{k}_{t+1} = \frac{s_t}{(1 + \mu)A_t n_t}. \tag{19}$$

Using (14) and (17) into (19), we have:

$$\hat{k}_{t+1} = \begin{cases} \frac{\beta[(1-\alpha)\hat{k}_t^\alpha + \bar{c}]}{D(1+\beta)(1+\mu)} & \text{for } \hat{k}_t \leq \hat{k}^*, \\ \Delta(\phi)[(1-\alpha)\hat{k}_t^\alpha(2-h_t^w)^{-\alpha}]^\theta[\bar{c} + 2(1-\alpha)\hat{k}_t^\alpha(2-h_t^w)^{-\alpha}]^{1-\theta} & \text{for } \hat{k}_t \geq \hat{k}^*, \end{cases} \quad (20)$$

where $\Delta(\phi) = \phi\beta/D(1+\mu)[(1+\beta)\phi + \gamma\theta]^{1-\theta}(\gamma\theta)^\theta$ is a positive constant. Using (15) in (20) defines a non-linear difference equation $\hat{k}_{t+1} = \xi(\hat{k}_t)$.

PROPOSITION 2. *Let Assumption 1 be satisfied. Then:*

- (i) *if $\bar{c} = 0$, then there exists a unique globally stable steady-state equilibrium for capital per effective unit of labour, $\hat{k}_{t+1} = \hat{k}_t = \hat{k}^{ss}$, such that female hours of work in the market are constant; and*
- (ii) *if \bar{c} is sufficiently small, then there exists at least one locally stable steady-state equilibrium for capital per effective unit of labour, $\hat{k}_{t+1} = \hat{k}_t = \hat{k}^{ss}$, such that in the neighbourhood of \hat{k}^{ss} female hours of work in the market increase with capital accumulation.*

Proof. When $\bar{c} = 0$, then

$$h_t^w = h^w(\phi) = \frac{2\gamma\theta}{(1+\beta)\phi + \gamma\theta},$$

which is less than one by Assumption 1. In this case, we have:

$$\hat{k}_{t+1} = 2^{1-\theta}\Delta(\phi)(1-\alpha)\hat{k}_t^\alpha \left[\frac{2(1+\beta)\phi}{(1+\beta)\phi + \gamma\theta} \right]^{-\alpha}.$$

Therefore, we can easily show that the difference equation $\hat{k}_{t+1} = \xi(\hat{k}_t)$ is strictly concave in \hat{k}_t and $\lim_{\hat{k}_t \rightarrow 0} \xi'(\hat{k}_t) = \infty$ and $\lim_{\hat{k}_t \rightarrow \infty} \xi'(\hat{k}_t) = 0$. This implies that there exists a unique globally stable steady-state equilibrium for \hat{k} . When $\bar{c} > 0$, then the difference equation $\hat{k}_{t+1} = \xi(\hat{k}_t)$ is represented by (20). There are several possible cases. However, when \bar{c} is sufficiently small such that $\hat{k}^*(\phi)$ is smaller than the capital stock per effective unit of labour in which the capital accumulation equation for $h_t^w = 1$,

$$\hat{k}_{t+1} = \frac{\beta[(1-\alpha)\hat{k}_t^\alpha + \bar{c}]}{D(1+\beta)(1+\mu)}$$

crosses the 45 degree line, then we can ensure that the difference equation $\hat{k}_{t+1} = \xi(\hat{k}_t)$ has at least one locally steady-state equilibrium, $\hat{k}_{t+1} = \hat{k}_t = \hat{k}^{ss}$, such that in the neighbourhood of \hat{k}^{ss} female hours of work in the market increase with capital accumulation. This follows from the fact that $\hat{k}_{t+1} = \xi[\hat{k}^*(\phi)] > \hat{k}^*(\phi)$ and we can show that $\lim_{\hat{k}_t \rightarrow \infty} \xi'(\hat{k}_t) = 0$, which completes the proof since $\xi(\hat{k}_t)$ is a continuous function of \hat{k}_t .

When $\bar{c} = 0$ preferences are homothetic and the substitution effect implies that fertility should decrease with capital accumulation and the wage rate, while the income effect implies that fertility increases with capital accumulation and the wage rate. The

log-utility implies that the substitution and income effects exactly cancel each other out, such that fertility and therefore female hours of work in the market are constant and do not vary with capital accumulation. When $\bar{c} > 0$, then preferences are not homothetic and households spend a larger fraction of their income on consumption in the first period of life as their labour income rises so that capital accumulation leads to a decrease in fertility.

2. Gender Barriers and Development: Analytical Results

In this Section, we derive some analytical results. For the model with $\bar{c} = 0$ we can analytically find the steady-state equilibrium of the capital stock per effective worker.

$$\hat{k}^{ss}(\phi) = \begin{cases} \left[\frac{\beta(1-\alpha)}{D(1+\beta)(1+\mu)} \right]^{\frac{1}{1-\alpha}}, & \text{if } \phi \leq \frac{\gamma\theta}{1+\beta}, \\ \frac{\phi}{[(1+\beta)\phi + \gamma\theta]^{\frac{1-\theta-\alpha}{1-\alpha}}} \left[\frac{2^{1-\theta-\alpha}\beta(1-\alpha)(1+\beta)^{-\alpha}}{D(1+\mu)(\gamma\theta)^\theta} \right]^{\frac{1}{1-\alpha}}, & \text{if } \phi > \frac{\gamma\theta}{1+\beta}. \end{cases} \tag{21}$$

For any $\phi > \gamma\theta/(1 + \beta)$, it is straightforward to see that an increase in gender discrimination, that is a lower ϕ , implies a decrease in the long-run capital stock per effective worker. Moreover, output per effective unit of labour is given by

$$\hat{y}^{ss}(\phi) = \begin{cases} \left[\frac{\beta(1-\alpha)}{D(1+\beta)(1+\mu)} \right]^{\frac{\alpha}{1-\alpha}}, & \text{if } \phi \leq \frac{\gamma\theta}{1+\beta}, \\ \frac{\phi[2(1+\beta)]^{1-\alpha}}{[(1+\beta)\phi + \gamma\theta]^{\frac{1-\alpha(1+\theta)}{1-\alpha}}} \left[\frac{2^{1-\theta-\alpha}\beta(1-\alpha)(1+\beta)^{-\alpha}}{D(1+\mu)(\gamma\theta)^\theta} \right]^{\frac{\alpha}{1-\alpha}}, & \text{if } \phi > \frac{\gamma\theta}{1+\beta}. \end{cases} \tag{22}$$

When $\phi > \gamma\theta/(1 + \beta)$ output per effective unit of labour is decreasing with gender discrimination in the labour market. If $\phi \leq \gamma\theta/(1 + \beta)$, then women will not participate in the labour market and discrimination will not have any effect on output.

PROPOSITION 3. *Let Assumption 1 be satisfied such that $\phi > \gamma\theta/(1 + \beta)$ and $\bar{c} = 0$. Consider two economies (economy A and economy B) in which the only difference between these two economies is the level of gender barriers to female labour force participation. Then:*

(i) *the ratio of output per effective worker of the two economies is given by:*

$$\frac{\hat{y}^{ss}(\phi^A)}{\hat{y}^{ss}(\phi^B)} = \frac{\phi^A [(1+\beta)\phi^B + \gamma\theta]^{\frac{1-\alpha(1+\theta)}{1-\alpha}}}{\phi^B [(1+\beta)\phi^A + \gamma\theta]^{\frac{1-\alpha(1+\theta)}{1-\alpha}}}; \tag{23}$$

(ii) *moreover, in the limiting case in which $\alpha(1 + \theta) \rightarrow 1$ (e.g. $\alpha \rightarrow 1/2$ and $\theta \rightarrow 1$), then the ratio of output per worker of the two economies is given by the ratio in the level of gender barriers to female labour force participation, that is*

$$\lim_{\alpha(1+\theta) \rightarrow 1} \frac{\hat{y}^{ss}(\phi^A)}{\hat{y}^{ss}(\phi^B)} = \frac{\phi^A}{\phi^B}. \quad (24)$$

Proof. This follows directly from (22).

In the particular case of the second item of Proposition 3, differences in output per worker amongst similar economies will be proportional to differences in gender barriers to female labour force participation as long as $\phi > \gamma\theta/(1 + \beta)$.¹⁸ Since in this model gender barriers are reflected in the gender wage gap, we could map differences in output per effective worker with reference to differences in the gender wage gap. For instance, if we consider a counterfactual economy similar to the US but with the gender wage gap of Egypt, then output per effective worker in the hypothetical economy would be 37% of the one in the US, as long as $\phi > \gamma\theta/(1 + \beta)$.¹⁹

Output *per capita* is given by

$$y_t = \frac{Y_t}{n_t P_t + P_t + \frac{P_t}{n_{t-1}}} = \frac{Y_t}{P_t} \frac{1}{\left(n_t + 1 + \frac{1}{n_{t-1}}\right)} = A_t \hat{y}_t \frac{1}{\left(n_t + 1 + \frac{1}{n_{t-1}}\right)}.$$

In the long run, the ratio in *per capita* output for economies A and B in the case in which $\bar{c} = 0$, $\phi > \gamma\theta/(1 + \beta)$, and $\alpha(1+\theta) \rightarrow 1$ would be given by

$$\frac{y_t^{ss}(\phi^A)}{y_t^{ss}(\phi^B)} = \frac{\phi^A \left[n(\phi^B) + 1 + \frac{1}{n(\phi^B)} \right]}{\phi^B \left[n(\phi^A) + 1 + \frac{1}{n(\phi^A)} \right]}. \quad (25)$$

When population is still growing over time, that is $n(\phi^i) > 1$, for $i \in \{A, B\}$, then the difference in output *per capita* between economies A and B will be larger than the difference in output per effective worker of these two economies.²⁰ The reason is that since fertility is higher when gender barriers to female labour force participation are higher, then the total dependency ratio, the ratio of those out of the labour force (children and old adults) to those in the labour force, is larger for economies with smaller ϕ .

What are the effects of gender discrimination in the labour market on welfare in the long run? On the one hand, gender discrimination decreases capital accumulation and therefore output, consumption and, consequently, welfare. On the other hand, it increases fertility, which has a positive effect on the utility of households. The utility costs of gender wage gaps might therefore be lower than the output costs. For the case in which $\bar{c} = 0$ and $\phi > \gamma\theta/(1 + \beta)$, it can be shown that in the long run the indirect utility of the representative household is given by

¹⁸ There is a limit of how gender discrimination in the labour market affects output per effective labour, since $\hat{y}^{ss}(\phi) \geq [\beta(1 - \alpha)/D(1 + \beta)(1 + \mu)]^{\frac{1}{1-\alpha}}$.

¹⁹ Otherwise, the output per effective worker of this counterfactual economy will be higher than 37% of the US economy.

²⁰ Quantity $[n(\phi)+1+1/n(\phi)]$ is negative related to ϕ when $n(\phi) < 1$.

$$V(\phi) = (1 + \beta) \left(\ln(\phi) - \left\{ \frac{[1 - \alpha(1 + \theta)]}{1 - \alpha} + \theta(\gamma + \beta) \right\} \right) \ln[(1 + \beta)\phi + \gamma\theta] + \vartheta_t, \quad (26)$$

where ϑ_t is a term which depends on the time trend t and all constants except ϕ . We can see that when the gender wage gap increases (ϕ decreases), then there are two effects on welfare: the first term on the right-hand side of (26) implies that welfare decreases; while the second term on the right-hand side of (26) suggests that welfare increases. Taking the derivative of $V(\phi)$ with respect to ϕ implies that:

$$V'(\phi) = (1 + \beta)^2 \theta \frac{\left[\frac{\gamma(1 - \phi)}{1 + \beta} + \phi \left(\frac{\alpha}{1 - \alpha} - \frac{\beta}{1 + \beta} \right) \right]}{\phi[(1 + \beta)\phi + \gamma\theta]}. \quad (27)$$

This derivative is positive if and only if the following condition holds:

$$\frac{\gamma(1 - \phi)}{\phi} + \frac{\alpha(1 + \beta)}{1 - \alpha} > \beta. \quad (28)$$

Observe that a sufficient condition for this inequality to hold is that $\alpha(1 + \beta)/(1 - \alpha) > \beta$ and this is satisfied for the common estimate of capital share of income ($\alpha = 1/3$), as documented by Gollin (2002).²¹ In addition, we expect condition (28) to hold for small values of ϕ . Therefore, a decrease in gender barrier to female labour force participation (an increase in ϕ) should, in general, increase welfare in discriminatory societies.

It is important to highlight that the analytical results were derived for a particular model in which fertility and female hours worked in the labour market are constant over time. Results were also derived for the long-run balanced growth path equilibrium and transitional dynamics were not considered. In order to solve for the transitional dynamics and to quantify the effects of gender barriers to female labour market participation in a more general framework in which fertility is not necessarily constant, we need to solve the model numerically. This is what we do next.

3. Gender Barriers and Development: Numerical Results

In this Section we quantify the cost of gender discrimination on output *per capita*. Our strategy is to choose parameter values consistent with empirical observations in the US and then perform counter-factual analysis by investigating the effects of gender barriers to female labour force participation on output *per capita* and other statistics.

3.1. Measurement: Replicating a Baseline Economy

Table 1(a), provides all parameter values as well as a note on how each parameter was obtained. Below, we describe our calibration in detail. The model period in our economy is taken to be 25 years. Therefore, each agent lives for 75 years. We start the model period in 1900 and the corresponding final year of analysis is after four periods, or in 2000.²² The capital share α is set to 0.40, which is consistent with Gollin (2002). We set the value of μ such that TFP growth in the US is equal to 1.5% per year, which is

²¹ If $\alpha = 1/3$, then condition (28) implies that $\beta < 1$, which is true by assumption.

²² After four periods the capital stock per unit of efficiency couple will be 95% of its steady-state level.

Table 1
Parameter Values, Basic Statistics, Baseline Economy

<i>Panel (a): Parameter values</i>		
Parameters	Values	Comment/observations
α	0.4	Capital share based on Gollin (2002)
μ	0.4509	Rate of TFP growth based on Greenwood <i>et al.</i> (2005 <i>a,b</i>)
β	0.3747	Calibrated to match the T-Bill annual real rate of return, 2.2%
γ	0.1220	Constant population level along the steady-state
D	2.184	Calibrated to match the average private cost of children/GDP
θ	0.965	Calibrated to match hours worked by women relative to hours worked by men in 2000
ϕ	0.63	Calibrated to match the US female to male earnings ratio in 2000
\bar{c}	0.4	Calibrated to match the US fertility rate adjusted for survival in 1900 (Goss, 2010)
\hat{k}_0	0.0505	Calibrated to match the US $y_{2000}^{US}/y_{1900}^{US}$ (Maddison, 2006)

<i>Panel (b): Basic statistics</i>		
	US economy	Baseline economy
ϕ (%)	63	63
y_{2000}/y_{1900}	7.0	7.0
$1 - h_{2000}^w/1 - h_{2000}^h$ (%)	60	55
$\phi w_{2000} h_{2000}^w/y_{2000}$ (%)	40	33
Real interest rate, 1975–2000 (%)	2.2	2.4
Fertility rate, 1900	2.6	2.43

consistent with the TFP growth rate in the US in the second half of the 20th Century (Greenwood *et al.*, 2005*a*).²³ We set the discount factor β such that the real rate of return of a risk free bond is roughly 2.2%, which is the average historical real rate of return on T-Bills from 1975 to 2000.²⁴ The altruism factor, γ , is calibrated so that the population is constant in the long-run equilibrium.²⁵ In the model, the fertility rate is 2.02 in 2000, which is close to the observed US level – fertility rate adjusted for survival to age 10 in the US is roughly 2 in 2000 (Goss, 2010). We set the values of the remaining five parameters – \hat{k}_0 , \bar{c} , ϕ , D , and θ – so that we approach five empirical observations for the US economy:

- (i) the ratio of *per capita* income in 2000 relative to its level in 1900;²⁶
- (ii) the fertility rate adjusted for survival to age 10 in 1900;²⁷

²³ According to Greenwood *et al.* (2005*a*), the annual growth rate of TFP in the US was 1.41% between 1900 and 1948 and jumped to about 1.68% between 1948 and 1974. After 1974 there was a productivity slowdown as the TFP growth rate decreased by about 0.57%. From 1995 to 2000 the TFP growth rate increased to about 1.2% per year. We normalise the initial TFP value to $A_0 = 1$.

²⁴ This is the T-Bills 12 months' nominal interest rate minus the consumer price index. For the T-Bills we use the H15 Table from the Board of Governors of the Federal Reserve System and the inflation of the consumer price index we took from the international finance statistics of the IMF.

²⁵ In the model, a household means a couple and their children. Therefore, $n = 1$ implies a fertility rate of 2 in the data.

²⁶ According to Maddison (2006), the 2000 real *per capita* income in the US was about 7 times higher than its level in 1900.

²⁷ According to Goss (2010) the fertility rate in 1900 adjusted by survival to age 10 was about 2.6. In our calibration, $\bar{c} = 0.4$, which is a number close to the number used by Greenwood *et al.* (2005*a*) in a similar environment.

- (iii) the female to male earnings in 2000;²⁸
- (iv) the ratio of female to male hours of work in 2000;²⁹ and
- (v) the average private cost of children (i.e. the opportunity cost of staying at home) as a share of GDP *per capita*.³⁰

Observe that the calibrated model matches most of the target values (see Table 1(b)), except the ratio of female to male hours of work in 2000 and the private cost of children as a share of the GDP *per capita*.³¹ Our model implies that women spend about 18% less hours in home activities in 2000 than in 1900. Estimates from Ramey and Francis (2009) suggest that the number of hours per woman in home production decreased by 40% from 1900 to 2000.³² Our model thus underestimates the reduction in the number of hours spent by women in home activities over the development process. However, we highlight that in our model the driving force in the reduction of time spent in home activities is capital accumulation. As argued by Greenwood *et al.* (2005b), there are other factors, such as technical progress in the home sector, that are important in accounting for the reduction in hours of housework.³³ Following Greenwood *et al.* (2005a), we could have increased parameter D in 1950 to mimic the technical progress that occurred in the home sector. This, however, would not have added any new insight to our analysis. In our model the capital-to-output ratio in 2000 is 5.77, which is higher than the one observed in the US economy, which is roughly 3.5 (Chen *et al.*, 2009). However, in our model we do not consider intangible capital. McGrattan and Prescott (2011) show that if one considers investment in R&D and innovation as intangible capital, then the average capital-to-output ratio in the US is 5.77.

²⁸ Data from the United Nations (2005) show that the female to male earnings ratio is equal to 63% in the US. This dataset uses National Accounts information and estimates the female to male earnings ratio using the non-agricultural wage, the female and male participation rates, and the female and male total populations. Using the Panel Study Income Dynamics (PSID) Olivetti and Petrangolo (2008) show that the gender wage gap is about 67.5%. We will make cross-country comparisons and the United Nations (2005) provide estimate of the female to male earnings ratio for a large sample of countries, including developing countries. Therefore, for comparison reasons we let the female to male earnings ratio to be equal to 63% in the baseline economy.

²⁹ According to Erosa *et al.* (2005), women worked 40% fewer hours than men. Men worked on average 37.6 hours per week while women worked 26.7 hours per week. About half of this difference in hours of work is accounted for by the gender difference in hours per worker (intensive margin) while the remaining part is accounted for by the gender difference in participation (extensive margin). We target the overall difference in hours worked since there is no extensive margin decision in our model.

³⁰ According to Haveman and Wolfe (1995) this ratio is equal to 40% in the US. See also Doepke *et al.* (2007).

³¹ The difference between the data value and the model value were 8% and 17.5% for the ratio of female to male hours of work in 2000 and the private cost of children as a share of the GDP *per capita*, respectively. We define $G(\Omega)$ as the vector containing the absolute percent deviation between model moments and data moments at a vector of parameters $\Omega = (\bar{k}_0, \bar{c}, \theta, D, \beta)$. We chose $\hat{\Omega}$ to minimise the mean of $G(\Omega)$. In our calibration the mean of $G(\hat{\Omega})$ is less than 5%. The median is less than 1%.

³² According to Ramey and Francis (2009), women spent on average about 50 hours per week in home activities in 1900, compared with about 30 hours per week in 2000.

³³ In fact, Cavalcanti and Tavares (2008) show that a decrease in the relative price of home appliances has a first-order effect in female labour force participation. In the current article, we abstract from technical progress in the home sector, so we underestimate the reduction of hours in home production. Finally, Cavalcanti and Tavares (2011) show that the process of development is accompanied in virtually all countries by two changes in economic structure: the increase in the share of government spending in GDP, and the increase in female labour force participation. They find evidence that these two changes are causally related.

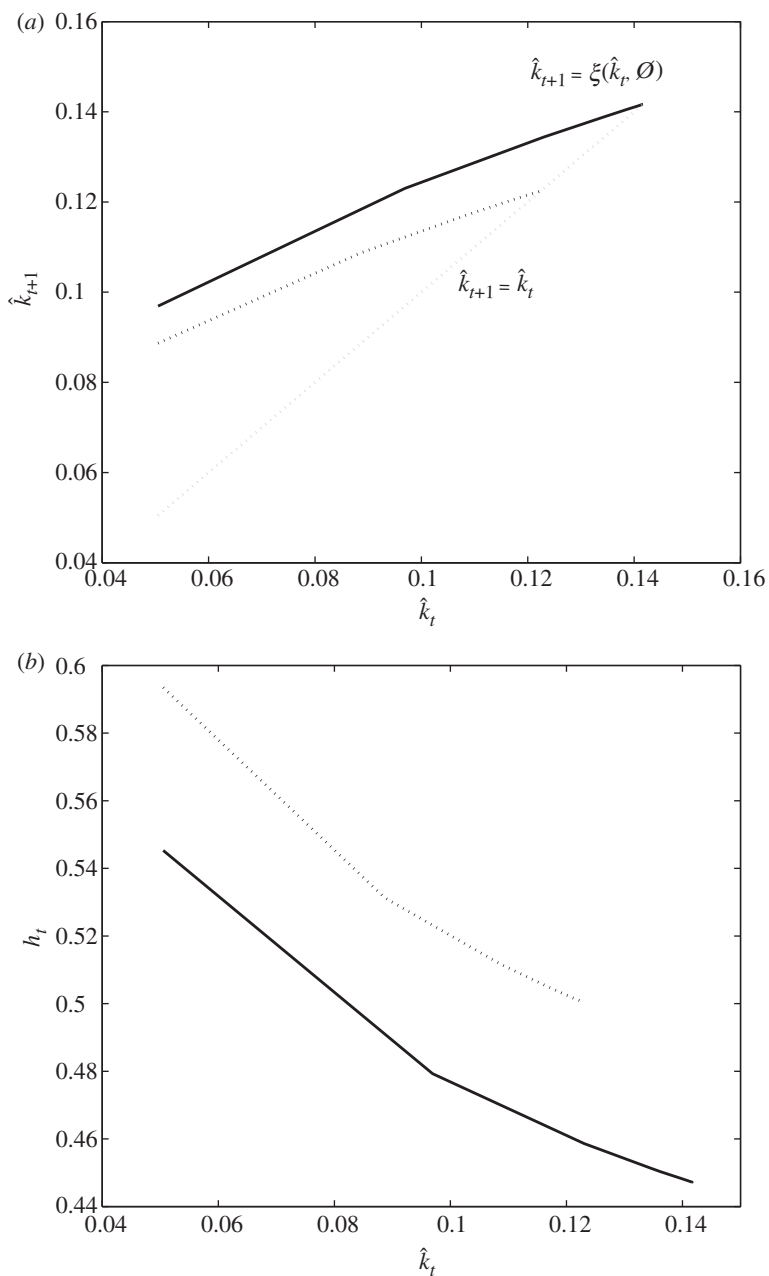


Fig. 1. *Baseline Economy. (a) Evolution of Capital Per Unit of Efficiency Couple. (b) Hours Worked Versus Capital Per Unit of Efficiency Couple*

Notes. Black solid line: Baseline economy; dotted black line: economy with 10% more gender inequality.

Figure 1 shows the evolution of the baseline economy, represented by the solid line. Figure 1(a) describes the evolution of the capital stock, with \hat{k}_{t+1} on the y axis and \hat{k}_t on the x axis, and the steady-state is found where this line is crossed by the 45

degree line. Simulations with the baseline parameter values show that there is a unique steady-state equilibrium for $\hat{k}_t > 0$.³⁴ Figure 1(b) shows the mechanics of the increase in women's hours worked: as capital is accumulated, then the opportunity cost of staying at home decreases fertility and increases female labour market participation. The dotted black line in both graphs describes an economy with a female-to-male earnings ratio in 2000 of 56.7% instead of 63%, as in the baseline economy. Observe that, in this case, the capital per unit of efficiency couple is lower and women work fewer hours in the market. In the following Section we exploit these 'cross-section' changes further.

3.2. Measurement: The Output Cost of Gender Discrimination

We now explore how the equilibrium properties of the model calibrated in the previous Section change with gender discrimination, measured by the female to male earnings ratio. We vary parameter ϕ and examine the model's predictions along three dimensions: output *per capita* as a fraction of US output *per capita*; female to male earnings ratio; and women's hours worked in the market. All statistics correspond to what would be observed in 2000.

Table 2 shows that as gender discrimination in labour market activities increases, the level of *per capita* output decreases, and hours spent by women in home activities increase. The effect of ϕ on output *per capita* is sizeable: a decrease in ϕ by a factor of two decreases output *per capita* by approximately 50%,³⁵ while hours at home increases by approximately 98%.³⁶ Welfare changes in the same direction of output, however, the welfare effects of gender barriers are smaller. Welfare effects are measured by the decrease/increase in permanent consumption such that the utility of the representative household in the baseline economy is similar to the economy

Table 2
Gender Inequality and Development: Quantitative Properties of the Model

	Output <i>per capita</i> , % baseline	Female to male earnings ratio	Hours at home, % baseline	Welfare % of consumption	Output <i>per capita</i> , % baseline (constant fertility)
US (baseline)	100	63	100	0	100
$\phi = \frac{1}{1.5} \times \phi_{\text{base}}$	69	42	152	-5.64	85
$\phi = \frac{1}{2} \times \phi_{\text{base}}$	50	32	198	-9.87	72
$\phi = \frac{1}{3} \times \phi_{\text{base}}$	42	21	222	-13.67	51

³⁴ We consider a fine grid for the capital stock, $\hat{\mathcal{K}} = [0 < \hat{k}^1 < \dots < \hat{k}^n]$, such that $\hat{k}^n = 100 \times \hat{k}$, in which \hat{k} is the steady-state value for the capital stock. In this grid we show that there is a unique-steady-state equilibrium for $\hat{k} > 0$.

³⁵ Output per worker decreases by 42%.

³⁶ $1 - h_i$ can be interpreted as the fraction of the female population that participates in labour market activities in a homogeneous couple setup.

with different gender barriers.³⁷ A decrease in ϕ by a factor of two decreases welfare by roughly 10%. This is a large effect on welfare but substantially smaller than the output costs.

As barriers to female labour market participation increase (i.e. ϕ decreases), there are two channels through which *per capita* output decreases.³⁸ First, output *per capita* decreases because women work fewer hours in the market (h_t decreases), and so output decreases for the same population. Second, output *per capita* also decreases because discrimination discourages women to work more hours in the market and decreases the couple's total income, leading couples to choose to have more children, that is, increase n_t .³⁹ What is the relative quantitative importance of the two effects in the overall impact of discrimination?

In the last column of Table 2 we present results for output *per capita* in the baseline economy when fertility is kept constant. We have solved a standard overlapping generations economy without fertility in which we feed exogenous values of h_t into the model as observed in each previous experiment. In this case, we are isolating the first channel through which gender discrimination affects output *per capita*, that is, the effect working solely through number of hours worked by women.⁴⁰ When the female to male earnings ratio decreases by a factor of two, output *per capita*, in the constant fertility case, decreases by 28 percentage points, compared to 50 percentage points in the first column. The effect of discrimination through women's hours at work accounts for about 46% of the total reduction in output observed in the model with endogenous fertility.

There is a limit on how gender barriers to female labour force participation can affect aggregate output and welfare. As ϕ decreases, then h_t^w increases until $h_t^w = 1$. Further decreases in ϕ would not change the amount of hours devoted to household chores once $h_t^w = 1$.⁴¹ The last row of Table 2 provides the case in which gender barriers are large and women do not participate in the labour market. Output would decrease by a 2.38 factor.

³⁷ Let the welfare measure be denoted by φ , then we have

$$\varphi = \left[\frac{(c_{b,t} + \bar{c}_t)}{(c_{a,t} + \bar{c}_t)} \left(\frac{d_{b,t+1}}{d_{a,t+1}} \right)^\beta \left(\frac{n_{b,t}}{n_{a,t}} \right)^\gamma \right]^{\frac{1}{1+\beta}}$$

where subscript 'b' denotes the baseline economy and 'a' the economy with a different level of gender barriers (ϕ). The welfare reported is the one of an economy with a different ϕ at 2000. When ϕ is reduced welfare is also reduced during the transition and along the balanced growth path equilibrium.

³⁸ *Per capita* output in this model is given by:

$$y_t = \frac{Y_t}{n_t L_t^p + L_t^p + (L_t^p / n_{t-1})}$$

The first term in the denominator corresponds to the number of existing children, the second term is the number of young couples, and the third term is the number of elderly couples.

³⁹ In our model, as discrimination limits utility gains through female participation and higher consumption, couples opt for increases in utility through fertility. This effect also accounts, in a larger model, for the lower opportunity cost of time spent at home, which is reflected in the decision to have more children.

⁴⁰ We can infer the role of fertility in the output decrease as the difference between the first and the last column.

⁴¹ Similar results will hold also when η is not sufficiently small and $h_t^h \in (0, 1)$.

3.3. Measurement: Counterfactual Analysis

The exercises in the previous Section describe the quantitative properties of the model for systematic variations in gender discrimination through wage inequality. We now feed the model with independent estimates of the female to male earnings ratio for several economies, keeping the other parameters exactly as in the baseline US economy. The purpose of this counterfactual exercise is to assess how much the level of US output *per capita* would decrease if gender discrimination were the same as in, say, Egypt. This will provide us with a first-ever macroeconomic estimate of how much of the existing difference in output *per capita* between Egypt and the US can be accounted for by differences in gender inequality in pay. In effect, we conduct this exercise for a large sample of countries. For each country, we feed in an independent estimate of gender wage inequality and compare the model's predictions with the relevant country data. We keep all parameters at their baseline values, except parameter ϕ , which we adjust until the female to male earnings ratio is similar to what is observed in the data.⁴² Table 3 reports results for selected economies.

We find that when fertility is endogenous, gender wage discrimination explains a large fraction of the difference in output *per capita* between some countries (see Table 3(a)) and the US. In the case of Saudi Arabia, barriers to female labour force participation explain almost the entire gap in relative output *per capita*. On the other hand, for Ireland the model over predicts the output gap between Ireland and the US.

Table 3
Empirical Data and Model Predictions for Reference Economies

Countries	Data		Model		
	Output <i>per capita</i> % of baseline	Female to male earnings ratio	Output <i>per capita</i> , % of baseline	Female to male earnings ratio	Output <i>per capita</i> , % of baseline (const fert)
US (baseline)	100	63	100	63	100
<i>Panel (a)</i>					
Ireland	91	53	87	53	94
Greece	56	55	90	55	96
Singapore	71	51	84	51	93
Saudi Arabia	37	16	42	16	65
Iran	19	39	64	39	82
Egypt	10	23	42	23	65
India	8	31	49	31	71
<i>Panel (b)</i>					
Finland	77	71	109	71	103
Norway	99	77	114	77	105
Sweden	77	81	117	81	107

Source. United Nations (2005)

⁴² In online Appendix B, we discuss three issues related to this approach: first, we consider an alternative measure of the gender wage gap, which is based on the 'unexplained' gender wage gap. We show that for the sample of countries in which we have measures of the 'unexplained' gender wage gap, results are similar using both measures. Second, we discuss how selection bias in female labour force participation could change our quantitative results. Finally, we consider issues related to the fact that countries might be in different stages of growth.

Notice that, were the US to have the level of gender pay inequality observed in Egypt, output *per capita* would be 42% of its actual level. Since output *per capita* in Egypt is 10% of that of the US, gender discrimination explains about 64% of the difference in output *per capita* between the two countries. When fertility is constant the model explains about 39 of the difference, still a sizeable fraction.⁴³

Table 3(b), shows what output *per capita* in the US would be if gender barriers were similar to what is observed in Finland, Norway, and Sweden. Scandinavian countries are particularly interesting because gender inequality in earnings is lower in these countries than in the US (see Table 3(b)) but output *per capita* is slightly lower than in the US. Our computations show that the US can increase output *per capita* significantly if gender inequality decreased to the level observed in Scandinavian countries. For instance, if gender inequality in the US were similar to the one in Sweden, output *per capita* would be 17% higher than the level observed in 2000.⁴⁴

Figure 2(a) summarises the performance of our model for 118 countries, first for the baseline model and then for the model with constant fertility. On the *y* axis is the value of country output *per capita* relative to the US level, as predicted by the model. On the *x* axis, we plot the value of the exact same variable, as observed in the data. If gender discrimination explained all of the difference in *per capita* output between a country and the US, the corresponding point would lie on the 45 degree line. The graphs reveal three extremely important features. First, the model tends to predict values of *per capita* output that are higher than those observed in the data. This is expected given that we focus only on barriers to female labour force participation and abstract from all other differences amongst countries, such as TFP differences, labour market institutions and government policies. We also abstract from the effects of gender discrimination on human capital, working through a decrease in young girls' access to education, which is also expected to be considerable. Second, for some countries, gender discrimination explains all of the difference in relative output levels, as shown by the cases where the point lies very close to the 45 degree line. Third, the model with endogenous fertility shows a stronger positive correlation between predicted and actual values, when compared to the exogenous fertility model. The differences between these two correlations are statistically different from zero at the usual confidence levels. Therefore, abstracting from fertility choice and considering only differences in female labour force participation might lead to misleading conclusions about the effects of barriers for women to work on development.

A final feature to notice is that for very poor countries gender barriers explain a low fraction of the difference in income level between these countries and the US. Very poor countries have a low level of gender inequality in earnings. In fact, Goldin (1995)

⁴³ Instead of using the female to male earnings ratio to estimate ϕ , we could have used the gender gap index (Hausmann *et al.* 2006), which is the synthesis of gender discrimination indices in health, education, and political and economic empowerment. To determine the parameter estimate for ϕ for each country we could have multiplied the ratio of the gender gap index of a country to the US value by the baseline $\phi = 0.63$. This is presented in online Appendix C. Notice that in this case, the experiments underestimate the gender wage gap and gender barriers explain a smaller fraction of international income differences (see Table C1 in online Appendix C). However, these experiments would require that the mapping of differences in the gender gap index would translate in the observed differences in ϕ .

⁴⁴ Welfare would be 3.73% higher relative to the baseline.

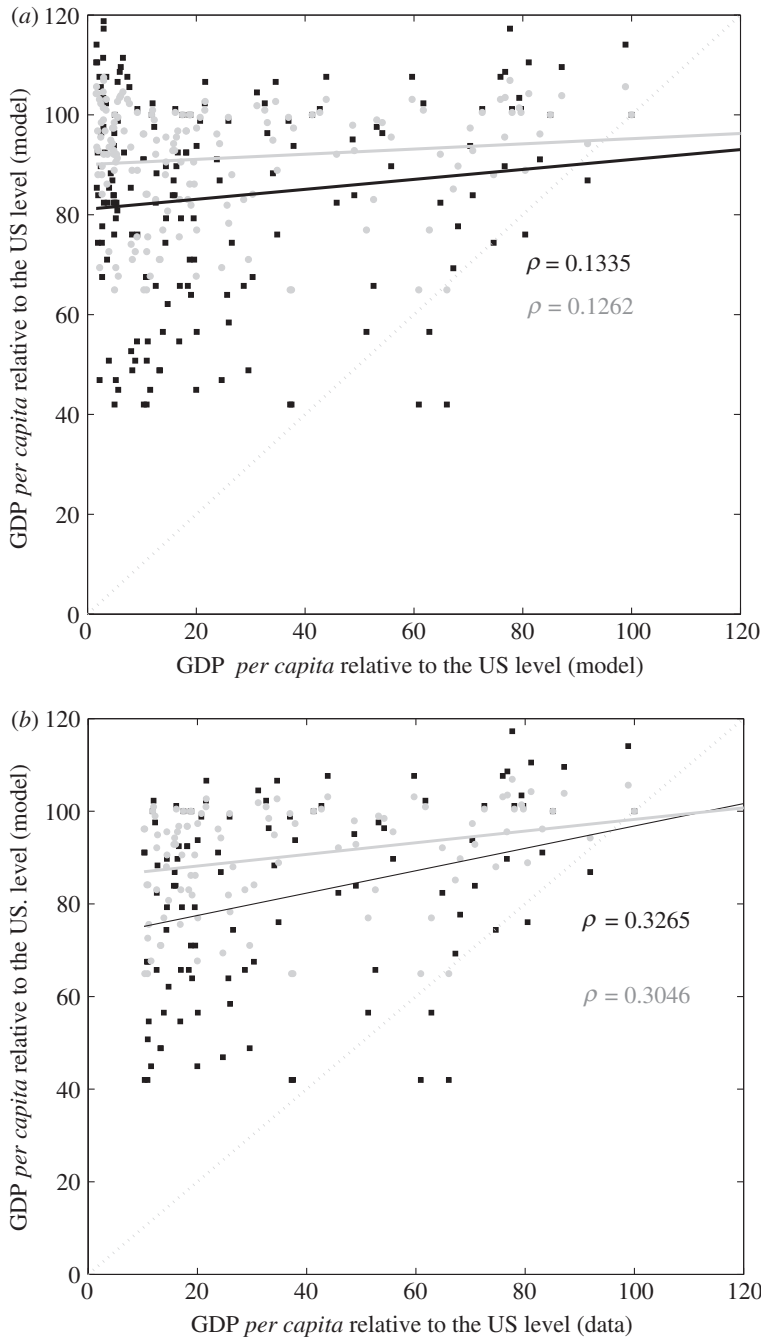


Fig. 2. Empirical Data and Model Predictions. (a) All Countries. (b) Countries with Income Per Capita Greater than 10% of the US Level

Notes. Black squares represent model predictions with endogenous fertility and the black solid line is the best linear fit. Grey circles and the accompanying grey solid line correspond to the constant fertility model. Dotted grey line: 45 degree line.

and Galor and Weil (1996) emphasise that female labour force participation has a U-shaped pattern. This is because female labour force participation is high and gender inequality is low in the traditional agriculture sector. Therefore, as in Galor and Weil (1996), our model is more appropriate for analysing economies that are consistent with the modern growth regime with a negative relationship between income and population growth (Galor and Weil, 2000). Figure 2(b) shows that the model has a better fit when we exclude from our simulations countries with output *per capita* that is below 10% of the US level. The correlation between model predictions and data is almost three times larger than when the whole sample is included. The difference in correlations between data and model, with and without endogenous fertility, is also statistically different from zero at any usual confidence level.

3.4. Causality in Gender Barriers

In our model, the gender wage gap derives from the existence of barriers to female participation in the labour market and is constant over time. Although there is empirical evidence showing that gender inequality is largely determined by social and cultural norms at the national level that hardly change in the short run (Fernandez, 2007), this does not imply that economic forces, including structural transformation, which raises women's relative wage, do not have an impact on those norms.⁴⁵ In this Section, we alter our benchmark model and let capital accumulation affect the extent of barriers to female labour force participation. This is an important modification and is in fact more consistent with the empirical evidence than the model in which gender barriers are constant over time. The benchmark model is, however, simpler to present and its analytical results are more straightforwardly derived. Nevertheless, it is important to investigate whether or not the quantitative results presented in the previous Section hold also in this framework with endogenous gender barriers. We view the results of this subsection not as a robustness check of the model with exogenous gender barriers but as the main quantitative analysis of the article. We assume that $\phi_t = \phi(\hat{k}_t)$ with $\phi'(\cdot) > 0$ so that gender barriers decrease as the economy develops. In particular, we let

$$\phi_t = \phi(\hat{k}_t) = \begin{cases} \phi_1 \times (1 + \hat{k}_t), & \phi_1 > 0 & \text{if } \hat{k}_t \leq \frac{1}{\phi_1} - 1, \\ 1 & & \text{if } \hat{k}_t \geq \frac{1}{\phi_1} - 1. \end{cases} \quad (29)$$

The rest of the framework is kept identical to that presented in Section 1. We calibrate the model to match the same statistics reported in Table 1.⁴⁶ In this case, the gender

⁴⁵ Hazan and Maoz (2002) provide an interesting model of the dynamics of female labour force participation based on endogenous changes of social norms. Doepke and Tertilt (2009) show how technical progress can lead men to choose the extension of women's rights.

⁴⁶ The calibrated parameter values are as follows: $\alpha = 0.4$, $\mu = 0.4509$, $\beta = 0.3747$, $\gamma = 0.123$, $D = 2.184$, $\theta = 0.965$, $\hat{k}_0 = 0.0518$, and $\phi_1 = 0.557$. Since barriers to female labour force participation decrease with capital accumulation, then $\phi_{1900} = 0.5859$ and $\phi_{2000} = 0.6325$. In addition, we have $y_{2000}/y_{1900} = 7$, $1 - h_{2000}^w/1 - h_{2000}^b = 0.55$, $\phi w_{2000} h_{2000}^w/y_{2000} = 0.34$. Fertility in the calibrated economy is equal to 2.58 in 1900 and 2.03 in 2000. Therefore, the fall in fertility in this model is more consistent with the fall observed in the data than with what is generated in the benchmark model. In the data, fertility adjusted by survival to age 10 decreased from 2.6 in 1900 to about 2 in 2000. The real rate of return is equal to 2.2% between 1975 and 2000 and the capital-to-output ratio is 5.8 in 2000.

wage gap decreases as the economy accumulates capital and develops, for two reasons: differences in productivity across genders decrease, and gender discrimination decreases in response to the higher relative wage of women. Figure 3 shows that

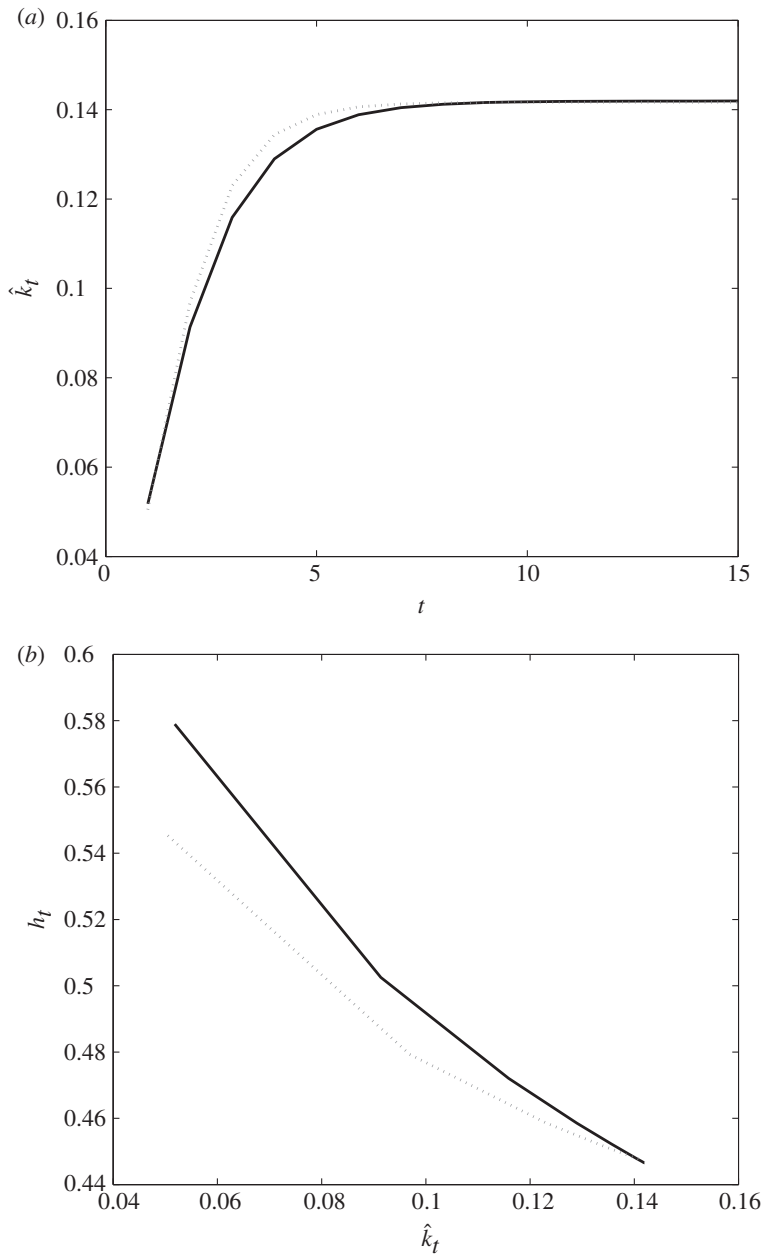


Fig. 3. *Model with Endogenous Gender Barriers. (a) Capital Per Unit of Efficiency Couple. (b) Hours Worked Versus Capital Per Unit of Efficiency Couple*
 Notes Black solid line: ϕ increases with \hat{k}_t ; dotted black line: ϕ constant.

qualitatively the two economies – with ϕ exogenous and ϕ endogenous – behave similarly in terms of capital per effective unit of the couple. The speed of convergence is faster when ϕ is exogenous than when ϕ depends on the capital stock.⁴⁷ Notice that the fall in hours worked at home is stronger with ϕ endogenous than when ϕ is exogenous. This is because not only the opportunity cost of staying at home increases with capital accumulation but also gender barriers decrease.

Table 4 provides some quantitative implications with the model presenting feedbacks from development to gender barriers (see Table 4). We vary the exogenous parameter ϕ_1 and examine the model's predictions along the same dimensions described in Table 2. Again, all statistics correspond to those observed for the year 2000. Results are very similar to those presented in Table 2. For instance, when ϕ_1 decreases by a factor of 2, output *per capita* decreases by 55%, while in the baseline case it decreased by 50%. Notice, however, that now the gender wage gap increases further, reflecting the additional assumption of endogenously decreasing discrimination. The female to male earnings ratio decreases from 63% to 29%, while in the baseline case it decreased to 32%. Therefore, to undertake a cross-country analysis, we would need a smaller variation in ϕ than in our benchmark model. For instance, a decrease in ϕ_1 so that the female to male earnings ratio is the same as in the baseline case (say 30%), delivers a decrease in output *per capita* that is roughly the same as when gender barriers were exogenous (and ϕ constant). This implies that a counterfactual analysis similar to the one implemented in subsection 3.3 would yield similar results for this case when gender barriers depend on the level of capital per effective unit of couple.

In Figure 4 we implemented an exercise similar to that shown in Figure 2. We changed ϕ_1 such that the model reproduces the gender wage gap observed in 2000 for the same 118 economies considered in Figure 2. First, notice the similarities of the two Figures: in general, the model predicts values of *per capita* output that are higher than those observed in the data; for some countries, gender barriers explain most of the

Table 4
Gender Inequality and Development: Quantitative Properties of the Model

	Output <i>per capita</i> , % baseline	Female to male earnings ratio	Hours at home, % baseline	Welfare % of consumption	Output <i>per capita</i> , % baseline (constant fertility)
US (baseline)	100	63	100	0	100
$\phi = \frac{1}{1.5} \times \phi_{\text{base}}$	65	40	159	-6.17	83
$\phi = \frac{1}{2} \times \phi_{\text{base}}$	45	29	211	-11	68
$\phi = \frac{1}{3} \times \phi_{\text{base}}$	42	19	218	-14	65

⁴⁷ The difference equation for capital per unit of efficiency couple $\hat{k}_{t+1} = \tilde{\xi}(\hat{k}_t)$ will be similar to that of (20), except that $\Delta[\phi(\hat{k}_t)]$ will be a positive function of \hat{k}_t and h_t^w will decrease faster with respect to \hat{k}_t . There are two effects on the speed of convergence. In the one hand, the speed of convergence increases because $\Delta(\phi)$ is positively related with ϕ and therefore with \hat{k}_t . In the other hand, h_t^w is decreasing in ϕ and this slows down convergence. In our numerical exercises, the second effect dominates the first one.

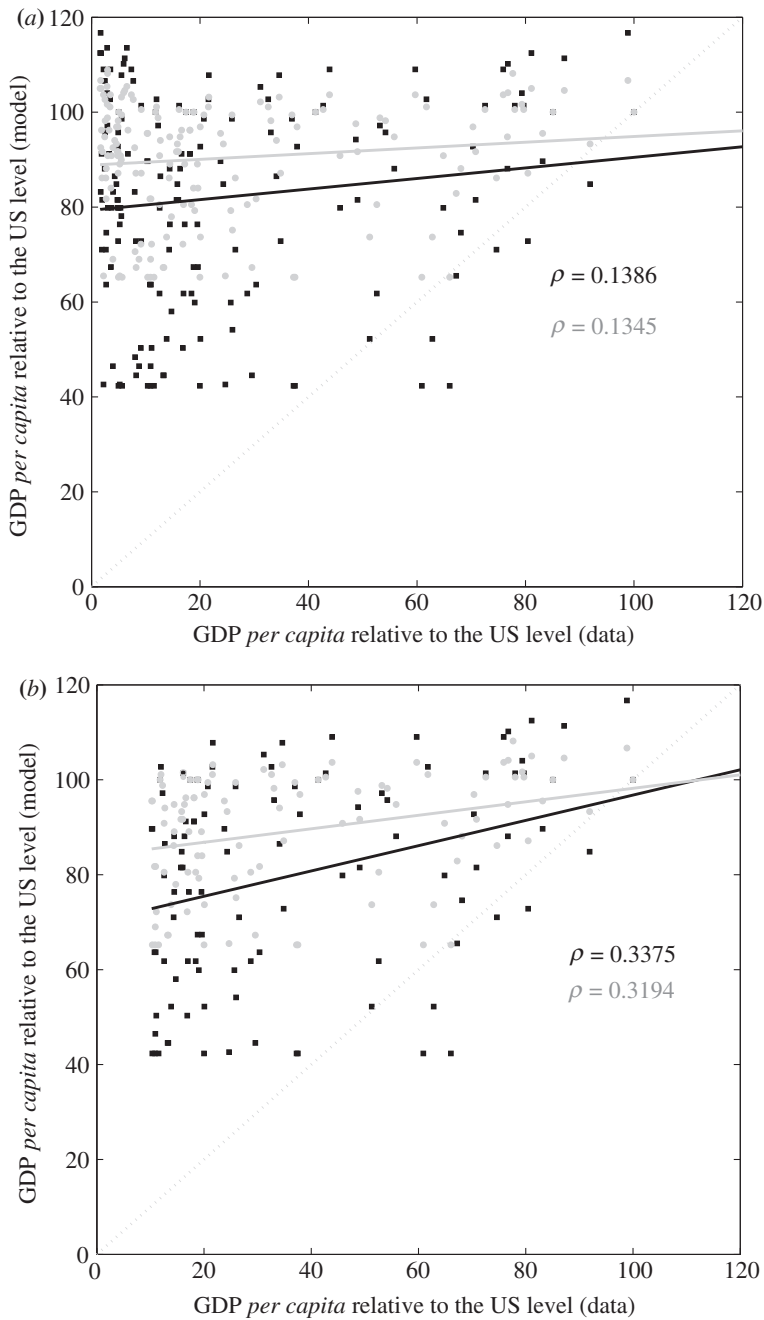


Fig. 4. Empirical Data and Model Predictions: Endogenous Gender Wage Gap. (a) All Countries. (b) Countries with Income Per Capita Greater than 10% of the US Level

Notes. Black squares represent model predictions with endogenous fertility and the black solid line is the best linear fit. Grey circles and the accompanying grey solid line correspond to the constant fertility model. Dotted grey line: 45 degree line.

difference in relative output levels; and the model with endogenous fertility shows a stronger positive correlation between predicted and actual values than the exogenous fertility framework. The difference between these two correlations are statistically different from zero at the usual confidence levels. The correlation between the predicted relative income of the models presented in Figure 2(a) and 4(a) is 0.9981 when fertility is endogenous and 0.9972 when fertility is exogenous.⁴⁸ For instance, for the case of Ireland in which the gender wage gap in 2000 is 0.53, the output *per capita* will be 86% relative to the calibrated model. This is very similar to the number found in Table 3, which for Ireland was 87% relative to baseline. For the case of Egypt, output *per capita* will be 42.4%, which is roughly the same number generated in Table 3.

4. Concluding Remarks

This article develops a model of economic growth where fertility and female labour market participation are endogenous as a way to estimate the output costs of gender discrimination. In our model, gender discrimination drives a wedge between women's labour productivity and female wages. We calibrate the model economy so that the long-run equilibrium matches key statistics of the US economy, including the gender wage gap. We then compare this benchmark economy with a counterfactual economy in which the value of all parameters are similar to those calibrated for the US economy, except for the gender wage gap. Gender discrimination decreases output *per capita* in two ways: it discourages female labour market participation, thus decreasing output; and it increases fertility and thus population in steady state, thus decreasing output *per capita*. The two channels have similar quantitative relevance, with the decrease in labour market participation coming out as slightly more important.

A counterfactual exercise using 118 developing and developed countries shows that for some economies a large fraction of country differences in output *per capita* can be attributed to gender inequality. For Saudi Arabia, gender discrimination explains all of its output difference relative to the US. Were the US to display the level of gender wage inequality present in, say, Egypt, its output *per capita* could drop by 58% relative to the initial level. This estimate is obtained by changing only the level of gender wage inequality in the US benchmark economy so that it matches Egypt's value, while maintaining all other parameters as those calibrate for the US economy. Our conclusion is that many countries can make substantially better use of their workforce and considerably increase output *per capita* by discouraging gender barriers in the labour market. This is also valid for the US. Output *per capita* would increase by 17% if gender inequality were reduced to the level observed in, say, Sweden.

Further research should concentrate on two issues. The first is how distinct mechanisms of gender discrimination – bias against participation versus wage discrimination – affect output. The second, and more important, is the relationship between gender discrimination and the accumulation of human capital. In particular,

⁴⁸ For the exercise in which we consider economies with *per capita* income larger than 10% of the US level, then these correlations are 0.9978 and 0.9967, respectively.

the discouragement of girls's education might have a strong impact on human capital and output *per capita*, as suggested in Greenwood *et al.* (2012).

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Additional Supporting Information may be found in the online version of this article:

Appendix A. Model with Gender Productivity Difference in the Labour Market.

Appendix B. Issues and Robustness.

Appendix C. Gender Inequality (ϕ) Based on the Gender Gap Index.

Data S1.

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