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The impact of sex-selective abortion technology on the evolution of postnatal gender-bias conventions*

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Abstract

A substantial body of research presents the absence of control on the family sex-composition as one of the main reasons for raising neglected young girls in context of rooted son preference. Therefore, one expects that egalitarian intra-family distributions of survival resources are more welcomed with the control of family sex-composition. In this paper, we model the (possible) relationship between the expansion in the use of the sex-selective abortion technology and the intra-family allocation of survival resources. The model allows us to find features of the environment that might prevent the expected trade-off between the acceptation of both behavioural traits: the control of the family sex-composition and the unequal allocation of survival resources.

Keywords: Evolution of conventions, cultural transmission, conformism, gender inequality.

JEL Classification: D1, D83, Z1

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1 Introduction

There are valuable states of being, such as being well-nourished, that virtually everybody aims to achieve. Females are said to be in disadvantage when the achievement of one valuable state of being means to sacrifice any other(s) valuable state(s) of being that males do not need to do. Meanwhile, the opposite situation rarely comes about. There is no wonder in a couple wanting that their children enjoy a 'good' life. Once they learn that their daughters will face more difficulties than their sons, they may prefer to bring up a boy rather than a girl.

In contexts of rooted female disadvantage, it is not difficult to find differences between people's behaviour towards their sons and towards their daughters. Among many other regions of the world for which female disadvantage is continually documented, let us consider the case of India. There the intrafamily allocation of survival resources in favor of sons is thought to be largely established (see Rosenzweig and Schultz[24], Dyson and Moore[10], and Sen[25], for several different approaches to the issue; and Murthi, Guio and Drèze[20], and Srinivasan[27], for findings from more recent studies). Distributing family resources unequally within the family is not a specific feature of India, indeed (see Chen, Huq and D'Souza[7], among a large body of literature). Neither is it specific of low-income countries. There is evidence of family resources being allocated in favor of sons also in high-income countries (see Ono[22]).

In this arena, the access to prenatal sex-detection technology has attracted a great deal of attention. This technology enables the person to control the family sex-composition by practising sex-selective abortions. As a consequence, atypically low numbers of female births (relative to the number of male births) become habitual figures. The question was first brought up by a piece of empirical research developed for the case of China (see Johansson and Nygren[14], Zeng et. al[30]). Thenceforth, evidence of gender-bias at birth is documented for several different countries (see Park and Cho[23], for the case of Korea; Junhong[15], for the case of China; and Sudha and Irudaya-Rajan[28], and Clark[6], for the case of India).

The cumulative impact of both behavioural traits -the allocation of survival resources unequally between sons and daughters and the practice of sex-selective abortions- has a great deal to do in explaining some dramatic demographic outcomes. Focus back on the case of India. With the exception of the state of Kerala, the number of young girls (relative to the number of young boys) is decreasing in every state of India (see Dyson[9]). These said ‘missing young girls’ would be a part of the additional number of females that would be alive in the absence of gender inequality, often denounced in the literature (see Sen[26], Coale[8], Johansson and Nygreen[14], Klasen and Wink[17], among others).

When people have the will to control the family sex-composition, but sex-selective abortion technology is of difficult access, people may control the sex-composition by failing to keep the planed family-size. That is, in the case of first children being of the wrong sex, the family size would be larger than wished (see Clark[6], among others). Therefore, couples are likely to bring up no wanted children who may become neglected children. When only wanted children are raised, these children are better provided for (see Goodkind[12], [13], Park and Cho[23], Lee, Feng and Campbell[21]).

Extrapolating their findings for the whole society, one expects a substitutive relationship between the acceptation of both behavioural traits. That is, one expects that a decrease in the number of female births (relative to the number of male births) is associated with an increase in the survival of young girls. In the paper we develop a model that captures the (possible) interrelationship in the evolution of both biases: the prenatal and the postnatal gender-biases. The model allows us to find environmental features that prevent a substitutive relationship between them. There the expansion in the use of sex-selective abortion technology fails to improve the survival of the young girls.

The rest of the paper is organized as follows. The following section revises the body of literature on cultural evolution. Then, we go on to model the evolution of postnatal gender-bias in the framework of cultural transmission models. This is developed in section 3. Our theoretical outcomes are included in section 4. The last section is devoted to interpret some of the empirical results released in the literature. There we conclude.

2 Cultural evolution

The traditional modelling strategies for individual choice of behavioural traits use the payoffs over traits as proxy for the whole reasons of choice. This modelling strategy does, however, fail to accurately predict the response of individuals to changes in their environment. Consider conformism as a cultural reason for choosing traits. Conformist individuals take care of the others’ opinion about their own actions. From their point of view, the perception that a trait will not be welcomed enough prevents them from acquiring it, even though the trait is associated with the highest payoff.

Capturing conformism as a separate reason for the choice of behavioural traits is in the spirit of the growing body of literature on conformist transmission (see the pioneering work by Boyd and Richerson[4], and Bowles[2],[3]) for recent literature). There, the common procedure to simulate the transmission of behavioural traits stems from the idea that people replicate traits unless they learn that switching traits becomes a better response to current evidence. This modelling strategy lies, indeed, in the individuals' cultural learning. To capture the cultural learning, Boyd and Richerson describe the next updating process. A person notices the current features of her environment by meeting another person that acquired any trait that she did not. Once the person is in the updating process, she updates in light of two informational sources: payoffs over traits and the acceptance of traits there.

It makes sense to consider both informational sources in our scenario. On the one hand, a substantial body of research supports the existence of a strong relationship between payoff differentials and gender-bias in the allocation of family resources (see for instance, Rosenzweig and Schultz' [24], there market opportunities are used as proxy for payoffs). It is worth noting that, moreover, the payoffs of behavioural traits are likely to correlate with the population distribution over the traits. In a growing body of research, the authors warn about the possibility that inequality against females decreases their survival and, moreover, it causes that terrible situation in which females become 'scarce'. Recall that by distributing unequally, mortality ratios are affected (see Park and Cho[23], and their note on the 'marriage squeeze').

On the other hand, no one doubts that the possibility of people's behaviour being public questioned on moral grounds can be thought as a quite reason to reject the unequal treatment of boys and girls, independently of its relative payoff. This is the main reason why the conformist transmission models are the framework of our paper.

At the same time, it is worth mentioning that conformist models capture the updating process by using a type of differential equations, called 'replicator equations'. These equations were introduced by the Evolutionary Biology (see Maynard-Smith and Price[19] and Maynard-Smith[18]) and, extended to the study of cultural transmission by Cavally-Sforza and Feldman[5], Boyd and Richerson[4] (see Bowles[2], [3] and Bisin and Verdier[1] for recent studies).

We contribute to this body of literature by incorporating foundational reasons to explain exogenous motives for switching traits. We consider the following. A person that cannot act in accordance to her 'beloved' value might act in accordance with another different value instead. Once this person is enabled to act in accordance with her value, she discards the previous one. In this way, our model might be a useful toolkit to study the possible relationship between the evolution of two conventions. The details of the model are presented in the following section.

3 The modelling framework

We design here a model of conformist transmission to simulate the evolution in the acceptance of the unequal allocation of survival resources. The model takes into account the impact that the expansion of sex-selective abortion technology might cause there. The section is organized as follows. After introducing the general notation and definitions in subsection 3.1, we set out the problem under study. Then we go on to present the model in subsection 3.3.

3.1 Preliminary notation and definitions

We first introduce some general notation and definitions. Let $N = \{1, \dots, n\}$ be the set of individuals under study. Consider a list of behavioural values, where c and d denote two of the values in the list. For each value and guided by her preferences, each person, $i \in N$, acquires one of the following two behavioural traits: acting in accordance or acting in discordance with this value.

The following definitions present plausible aspects of the individuals' personality. Regarding a value c,

Definition 1 ***(Substitutive Aspect)*** *A person has a Substitutive aspect* ***(S)*** *when, for the acceptance of c, this person considers the acceptance of another different value as a relevant informational source.*

Definition 2 ***(Payoff Difference Aspect)*** *A person has a Payoff Difference aspect* ***(PD)*** *when, for the acceptance of c, this person considers the difference between the payoff associated to act in accordance with c and the payoff associated to reject this value as a relevant informational source.*

Definition 3 ***(Conformism Aspect)*** *A person has a Conformism aspect **(C)** when, for the acceptance of c, this person considers that the acceptance of c in her society is a relevant informational source.*

For each value, a convention becomes established when one expects that the percent of population that acts in accordance with the value will remains constant over time. In other words, a convention arises out of an equilibrium in the population distribution related to a behavioural value. Population distributions are represented by vectors of dimension 2, denoted by $(p, 1-p)$, where $p \in [0, 1]$. The first element captures the population frequency that acquires a behavioural trait in accordance with the value, and the population frequency that rejects such a behavioural trait is expressed by the second element. For analytical purposes, we call 'interior conventions' to the conventions $(p, 1-p)$ with $p \in (0, 1)$. Meanwhile, we call 'degenerate conventions' to those $(p, 1-p)$ with $p \in \{0, 1\}$.

Exogenous perturbations might move society away from one equilibrium, displacing the current convention. That is, the population frequency that acts in accordance with one value may increase or decrease over time. It might also remain stable. In particular, it remains stable from the period t whose current convention is a 'stochastically stable equilibrium'. This is when small, but persistent population dynamics are endogenously corrected (see Maynard-Smith and Price[19] for a pioneering work in the study of the stability of conventions, and Foster and Young[11], Kandori, Mailath and Rob[16], Young[29] for pioneering works in the study of stochastically stable equilibriums).

At the risk of some oversimplification, for each value, a chain of conventions (equilibriums) describes the evolution of this value. That is, given a value c, a chain of c-conventions describes how the value is strengthened (weakened) or remain constant over time. Furthermore, when no confusion arises, the evolution of the value c is told the evolution of the c-conventions themselves.

The next definition presents the relationship -if any- in the evolution of values. Then

Definition 4 *A value, c, is said 'substitutive' for another, d, if every strengthening (weakening) of c modifies the environment, and as a consequence, value d weakens (strengthens) untill everybody acts in discordance with this value. Otherwise, value c is said 'additive' to value d.*

As defined here, within the c-conventions, one interior convention that it is an stochastically stable equilibrium guarantees against a substitutive relationship. Certainly, this is compatible with the following relationship. The value c is weakened as consequence of the strengthening of value d if an unstable c-convention becomes currently established. Therefore, we devote the label 'locally substitutive for' to capture local substitutive relationships. Formally,

Definition 5 *Consider the convention established in reference to a value d. A value c, is said 'locally substitutive' for d in a period t, if the strengthening (weakening) of c modifies the environment, and as a consequence, value d weakens (strengthens) from t to $t+1$.*

There is no need to introduce a formal definition of 'locally additive relationship' because every value that it is locally additive to another is, at the same time, additive to this one.

3.2 The problem

In this study we focus on two values, both of them rooted in contexts of female disadvantage. The first one concerns the allocation of household resources. The conventions relating this value describe the acceptance of gender-bias in the allocation of survival resources. We refer to these conventions as the postnatal gender-bias conventions, 'postnatal conventions' in short. The second value is on the family sex-composition decisions. The conventions describe the acceptance of the use of sex-selective abortion technology in order to determine the sex of the offspring. We call these conventions the prenatal gender-bias conventions, 'prenatal conventions' in short.

The problem that we examine is the following. We research into the conditions by which every expansion in the use of sex-selective abortion technology weakens the support of postnatal conventions. In such circumstances, the prenatal conventions are substitutive for postnatal ones. We also research into the conditions by which the two type of conventions are additive to each other.

In this respect, the impact of prenatal conventions are thought as exogenous perturbations in the evolution of postnatal conventions. The origins of these perturbations are, indeed, in the substitutive aspects of individuals. The increase in the access to sex-selective technology causes population dynamics of postnatal traits provided that there is a portion of the population that allocates survival resources unequally only if they fail to control the family sex-composition. Once they are able to control it, they feel discouraged to allocate unequally.

Moreover, we drop out the case in which an expansion of sex-selective abortion technology encourage people to allocate equally. This situation is hardly ever in the reality (see Goodkind[12], [13], Park and Cho[23], Lee, Feng and Campbell[21]), and the mathematical analysis is straightforward to the one we study here.

3.3 The dynamics of postnatal conventions

For simplicity and without loss of generality, the discussion will be carried out as though there are two separate type of individuals, $A, B \subseteq N$. Formally, $A \cap B = \oslash$, and $A \cup B = N$. For all $i \in N$ we assume the following.

> $i \in A$ if and only if, i has a **PD** or a **C** feature, or both of these features,
>
> $i \in B$ if and only if, i has a **S** feature.

It implies that people have two reasons for preference change: the evolution of prenatal conventions (exogenous reason) and the own evolution of postnatal conventions (endogenous reason). Nevertheless, people who respond to the evolution of both type of traits are also welcomed. They can be thought as if each one were two individuals: one responds to the evolution of prenatal conventions (then, it is in A), and the other responds to the evolution of prenatal conventions (then, it is in B). It is worth noting that in contrast to earlier conformist models, the propensity of people to switch traits varies across personality groups.

To proceed, we introduce the elements of the replicator equation that captures the existence of these two type of individuals. For a period of time t, the percent of people that allocates unequally can be decomposed as follows.

$$p^t = \frac{a^t}{\#N} + \frac{b^t}{\#N}, \tag{1}$$

where a^t represents the number of individuals in A that unequally allocates survival resources, b^t refers to the population in B that allocate unequally, and $\#N$ denotes the number of individuals in the society.

The additive relationship in (1) implies the possibility of studying the evolution of p^t by analysing evolution of each part separately. This property simplifies the exposition, indeed. We start first by presenting the propensities of people in A to switch traits. Then we go on to present the same propensities for people in B.

For this purpose, consider π the functions that assign payoffs over traits to population distributions. To capture the idea that it is possible to find a situation where an additional number of people allocating unequally decreases the payoff of this trait, the functional form of π is supposed to satisfy the first and second order conditions of an optimization problem. Consider the population distribution over postnatal traits, $(p, 1-p)$. The value π_p^{UNEQ} represents the payoff of allocating unequally and π_p^{EQ} the payoff of allocating equally.

Conformism is captured in the replicator equations by the difference between the population frequency that acts in accordance with the value, and the percent of population needed to switch to this trait (see the pioneering work by Boyd and Richerson[4]). Then, let $k \in [0,1]$ be the percent of population needed to understand that a behaviour is welcomed enough. The propensities to switch traits conditional on having the personality of A are given by

$$r^{UNEQ}(p|A) = r_{p|A}^{UNEQ} = \lambda(p^t - k) + (1-\lambda)(\pi_p^{UNEQ} - \pi_p^{EQ}), \tag{2}$$

$$r^{EQ}(p|A) = r_{p|A}^{EQ} = \lambda(k - p^t) + (1-\lambda)(\pi_p^{EQ} - \pi_p^{UNEQ}), \tag{3}$$

where parameter $\lambda \in [0,1]$ *weights up the importance of* ***PD*** *and* ***C*** *on updating.*

Equations (2) and (3) can be read as the propensity of people guided by **PD** and **C** personality aspects to switch to allocating unequally and to allocating equally, respectively. Regarding the propensities to switch traits conditional on having the personality of B, consider the following. The growth rate of sex-selective abortion technology, denoted $\rho \in [0,1]$, shows the probability of switching traits due to the evolution of prenatal conventions. Then, the propensities are given by

$$r^{UNEQ}(p|B) = r_{p|B}^{UNEQ} = 0, \quad and \tag{4}$$

$$r^{EQ}(p|B) = r_{p|B}^{EQ} = \rho. \tag{5}$$

Equations (4) and (5) can be read as the propensity of people guided by **S** personality aspect to switch to allocating unequally and to allocating equally, respectively. Equation (4) takes value zero to capture the idea that there is no reason why people that had the ability to control the family sex-composition lose it now. At the same time, note that equation (5) is invariant to the value of p. Indeed, the writing procedure is to keep the spirit in equations (2) and (3).

Assuming that people learn about current payoffs and the current support of postnatal traits by interacting with a person who does not behave as they do. For a population distribution, $(p^t, 1-p^t)$ satisfying equation (1), the probability of a person in A having the chance of judging the adequacy of their own beliefs is given by $p^t(1-p^t)$. Then, the evolution of a^t is given by

$$a^{t+1} = a^t + \#Ap^t(1-p^t)(r^{UNEQ}_{p^t|A} - r^{EQ}_{p^t|A}), \tag{6}$$

where $\#A$ denotes the cardinality of A.

Equation (6) is additively separable in two terms. The first term, a^t, refers to the population in A who acquires postnatal traits in the period of reference. This is to capture the path dependence structure in the evolution of conventions. The second term captures the endogenous differential. The sign of this differential informs if population dynamics benefit or, on the contrary, if they harm postnatal traits.

On the other hand, people are thought to learn about the access to technology as soon as available. Then, the evolution of b^t follows a decreasing pattern to be represented by the following equation.

$$b^{t+1} = b^t(1 - r^{EQ}_{p^t|B}). \tag{7}$$

Note that the evolution of b depends on the technological growth, ρ, by (5). If $\rho \in (0, 1]$ varies over time, the evolution of b^t is represented by a decreasing pattern converging to value zero, but at a variable ratio. Therefore, in order not to diver attention, ρ is thought as time invariant. Henceforth, we assume ρ is a parameter in the interval $(0, 1]$. We drop out $\rho = 0$ to eliminate the trivial case in which there are no exogenous perturbations.

Substituting equation (5) into (7), one obtains the exogenous differential, $b^t\rho$. This differential $b^t\rho$ captures the number of individuals that, by gaining access to sex-selective abortion technology, feel discouraged to allocate unequally within the family. Then, considering assumptions displayed by equations (1) to (7), one gets that

$$p^{t+1} = p^t + \frac{1}{\#N}[\#Ap^t(1-p^t)(r^{UNEQ}_{p^t|A} - r^{EQ}_{p^t|A}) - b^t\rho]. \tag{8}$$

Equation (8) shows the version of the replicator equation that we use to study the evolution of postnatal conventions, and its relationship with the evolution of prenatal conventions. This is an additively separable equation. The first term, p^t, captures the population frequency that acquires postnatal traits in the period of reference. The latter term shows the portion of the population that switches traits from one period to the next (the drift). Formally,

$$\dot{p} = \frac{dp}{dt} = p^{t+1} - p^t = \frac{1}{\#N}[\#Ap^t(1-p^t)(r^{UNEQ}_{p^t|A} - r^{EQ}_{p^t|A}) - b^t\rho]. \tag{9}$$

Positive values of (9) mean that the postnatal convention is strengthened over time. On the contrary, negative values of this equation means that the postnatal convention is weakened. In order that a pattern of behaviour can be anticipated, and then be likely to become a convention, this variation has to take value zero. In order to examine the existence of stochastically stable equilibriums (stable conventions), it is convenient to rewrite equation (9) as follows.

$$\dot{p} = \dot{p}^{En} + \dot{p}^{Ex}, \tag{10}$$

$$\textit{where } \dot{p}^{En} = \tfrac{\#A}{\#N}p^t(1-p^t)(r^{UNEQ}_{p^t|A} - r^{EQ}_{p^t|A}), \textit{ and } \dot{p}^{Ex} = \tfrac{-b^t\rho}{\#N}.$$

Equation (10) shows the drift in two separate terms. The first term, $\dot{p}^{En}$, captures the part of the drift caused by the population dynamics (the endogenous differential). The latter term, $\dot{p}^{Ex}$, expresses the change due to the expansion of technology over time (the exogenous differential). Moreover, note that (10) implies that the portion of the population that switches traits can be time invariant, even though the exogenous differential decreases over time. Indeed, by definition in equation (7), we get

$$\frac{d\dot{p}^{Ex}}{dt} < 0. \tag{11}$$

The next subsection presents the findings reached by studying the dynamics of the drift.

4 Results

The model developed in the previous section lies in the idea that the evolution of prenatal conventions causes perturbations on the scenario of postnatal conventions. A portion of the population is enabled to control the family sex composition and, as a consequence, they feel discouraged to allocate survival resources unequally. In this arena, prenatal conventions are additive to postnatal conventions if the perturbations leads people to allocate equally within the family. Therefore, some necessary conditions in order that a stable convention is established are worth noting. They are presented by the following proposition.

Proposition 1 *Assuming the support of postnatal traits evolves according to equation (8), and there exists a period t, in which $b^t > 0$. If $(p^*, 1 - p^*)$, where $p^t = p^*$, is a stable convention, then the following is hold.*

> *(i) There exist endogenous mechanisms that compensate the exogenous differentials, and only the differentials. Formally,*
>
> $$\frac{d(\dot{p}^{En})}{dp} = -1. \tag{12}$$
>
> *(ii) The portion of the population that updates in light of conformism and payoffs is at least the portion of the population that allocates unequally,*
>
> $$\frac{\#A}{\#N} \geq p^*. \tag{13}$$
>
> *(iii) The convention $(p^*, 1 - p^*)$ is interior: $p^* \in (0, 1)$.*

Proof: *(i)* follows from the condition $\dot{p} = 0$ for stable conventions. It implies that $\dot{p}^{En} = -\dot{p}^{Ex}$, for all t, by (10). Recall that $\dot{p}^{Ex} \leq 0$ by definition. In particular, equation (7) and $b^t, \rho > 0$ implies the following. In $t + 1$, the exogenous perturbation takes value $\frac{-b^t\rho}{\#N} < 0$. An endogenous response that fails to compensate exactly this exogenous perturbation moves society away the equilibrium, p^*. Moreover, the distance to p^* increases steadily until the period $t + \epsilon$, where $b^{t+\epsilon} = 0$ by (7) (see Remark 1).

(ii) follows from the convergence of b^t to value zero in $t + \epsilon$. By (8), we get $p^t = p^{t+\epsilon} = p^*$ only if $a^{t+\epsilon} = a^t + b^t$. It implies that $\frac{\#A}{\#N} \geq p^*$.

Moreover, it is straightforward to show *(iii)*. By $b^t > 0$, we learn that at least there is a percent of people that allocates unequally. Then $p^* \neq 0$. On other hand, the evolution of b^t implies that there are people that allocate equally over time. Then $p^* \neq 1$. □

The conditions in Proposition 1 mean that the chain of postnatal conventions includes any stable convention if there are enough people in A (Condition (*ii*)) learning that switching to allocate unequally becomes their best response under the new environmental features (Condition (*i*)). Formally, the latter requires that

$$r^{UNEQ}_{p^* - \frac{\rho b^t}{\#N}|A} > r^{EQ}_{p^* - \frac{\rho b^t}{\#N}|A}, \quad \text{If } \ b^t \neq 0. \tag{14}$$

Moreover, Proposition 1, (*iii*), also implies equality in propensities to switch traits when evaluated in p^*. That is,

$$r^{UNEQ}_{p^*|A} = r^{EQ}_{p^*|A}. \tag{15}$$

The equality in propensities to switch traits displayed by (15) follows from the convention $(p^*, 1-p^*)$ being interior. It implies that there exist at least two people that behave differently from each other, and so they are in the updating process. As a consequence, they have the chance of switching traits. The difference between propensities informs whether replication is, on average, the best response. Unequal propensities trigger an endogenous drift that moves society away the equilibrium. The convention remains stable provided that there exists an exogenous drift (equal in size and opposite in sign to the endogenous one, see (10)). At the same time, notice that the exogenous differential takes value zero in $t+\epsilon$, where $b^{t+\epsilon} = 0$. This is by (7). Then, from $t+\epsilon$, stability requires that the $\dot{p}^{En} = 0$. By (10), it requires equality in propensities to switch traits.

The following Remarks present sufficient conditions to find that prenatal gender-bias conventions are substitutive for postnatal conventions.

Remark 1 *Assuming the support of postnatal traits evolves according to equation (8) and $\#B > 0$. Then $\frac{d(\dot{p}^{En})}{dp} \neq -1$ implies the following. If there exists any stochastically stable convention, this is the one where everybody allocates equally* $(0, 1)$.

Note that Remark 1 states that if $\frac{d(\dot{p}^{En})}{dp} \neq -1$, then prenatal conventions lead individuals to allocate equally. The reason why $(0, 1)$ is a stable convention follows from nobody being in the updating process. Recall that if $\#B > 0$ and $p \neq 0$, there are exogenous drifts and people in the updating process. Then, we get the following. On the one hand, $\frac{d(\dot{p}^{En})}{dp} < -1$ implies that there exists any period of time in which the value is strengthened due to exogenous drifts. Certainly, the endogenous mechanism compensate each percent of population that exogenously switches to allocate survival resources equally and, moreover, it incorporates an additional number of people who allocates unequally. Then, the postnatal conventions become strengthened with the perturbations. As mentioned above, the study of this case is beyond the study of the paper due to the lack of empirical evidence that support its existence. On the contrary, $\frac{d(\dot{p}^{En})}{dp} > -1$ implies that the endogenous mechanism fails to incorporate enough people to substitute those individuals that exogenously switch traits. In such a case, the expansion in the use of sex-selective abortion technology trigger the weakening of postnatal conventions.

Proposition 2 *Assuming the support of postnatal traits evolves according to equation (8), and equation (13) is satisfied for all t. Prenatal conventions are additive to postnatal conventions if there exist endogenous mechanisms that compensate exogenous drifts.*
*Moreover, if there are people with **S** feature that allocates survival resources unequally, then prenatal conventions are additive to postnatal conventions if and only if these endogenous mechanisms exist.*

Proof: It is straightforward to proof Proposition 2. We start by considering the first part of this Proposition. For this purpose, recall that -because (13) is satisfied for all t- we can find people that takes advantage of allocating unequally if anyone switches to allocating equally. Therefore, the endogenous mechanisms guarantee that exogenous drifts fail to move society away every equilibrium (representing both, interior and degenerate conventions).
Regarding the latter part of this Proposition, it is worth noting the result in Proposition 1. There we get that the existence of endogenous mechanisms is a necessary condition for the stability of interior conventions under these environmental features (replication of postnatal traits evolves according to (8) and there are people in B that allocate unequally). Then, one goes on to examine if degenerate conventions that are stable require the existence of endogenous mechanisms. On the one hand, because there are people with S feature, $(1, 0)$ fails to be a stochastically stable equilibrium. $\#B > 0$ guarantees that there will be someone allocating equally over time. On the other hand, there is no wonder that the existence of endogenous mechanisms is no necessary if $(0, 1)$ is established as convention. However, this equilibrium fails to guarantee against a substitutive relationship. If the evolution of prenatal conventions cause postnatal conventions to be represented by $(0, 1)$, one gets that prenatal conventions are substitutive for postnatal ones (see Definition 4). □

Therefore, one starts by wondering about the conditions in order that an interior convention becomes established. Then one goes on to examine the conditions in order that the endogenous mechanism in (12) compensate for the systematic negative exogenous differentials. We devote the next subsection to this purpose.

4.1 The endogenous mechanism

As mentioned above, in order that prenatal conventions are additive to postnatal conventions, the chain of postnatal conventions have to include at least one interior stable convention. Therefore it requires that the propensity to switch to allocating equally equalizes the propensity to switch to allocating unequally (see (15)). Recall that by definition (displayed in equation (2) and (3)), the value of the propensities are given by the conformist effects, and also by the payoff difference effects. Notice that equality in propensities requires the following

$$(p-k)\frac{\lambda}{1-\lambda} = \pi_p^{EQ} - \pi_p^{UNEQ}. \tag{16}$$

Equation (16) means that in the event of the conformist aspect having no effect at all on the updating process, the payoffs are the only relevant information. Then, the equality in payoffs, $\pi_p^{UNEQ} = \pi_p^{EQ}$, is a necessary condition in order that an interior convention becomes established. On the other hand, if the conformist aspect is the only relevant information, the condition to arrive at an interior convention is the following. The population frequency that acts in accordance with the convention equalizes the value of population frequency needed to switch to allocating unequally, $p = k$.

In our scenario, we have great reasons to believe that both informational sources are taken into account by individuals in the updating process. In such a case, if one person or more update, the necessary and sufficient condition for there being an equilibrium is the following. The payoff effects and the conformist effects compensate for the effects of each other. In other words, there the higher payoff corresponds to the weakly supported trait.

Once an interior convention is established, the stability condition requires the existence of endogenous mechanisms (see Proposition 1, (i)). It implies the following relationship.

Proposition 3 *Consider the interior convention, $(p, 1-p)$. If there exist endogenous mechanisms satisfying (12), the following is hold.*

$$\pi'_{EQ} - \pi'_{UNEQ} > \frac{\lambda}{(1-\lambda)} \geq 0, \tag{17}$$

where π'_{UNEQ} denotes the derivative of of π_p^{UNEQ} with respect to population frequency, and, π'_{EQ} denotes the derivative of π_p^{EQ} with respect to population frequency.

Proof: In order to proof Proposition 3, the following is worth noting. The derivative of the endogenous mechanism, $\dot{p}^{En}$ in (10), with respect to population frequency is given by

$$\frac{d(\dot{p}^{En})}{dp} = \frac{\#A}{\#N}[(1-2p)(r_{p|A}^{UNEQ} - r_{p|A}^{EQ}) + p(1-p)(r'_{UNEQ} - r'_{EQ})], \tag{18}$$

where r'_{UNEQ} denotes the derivative of of $r_{p|A}^{UNEQ}$ with respect to population frequency, and, r'_{EQ} denotes the derivative of $r_{p|A}^{EQ}$ with respect to population frequency.

The first part of equation (18) takes value zero when evaluated in an interior equilibrium (see (15)). Then one focuses on the values of the second part of this equation. It implies: $r'_{UNEQ} - r'_{EQ} = -\frac{\#N}{\#Ap^*(1-p^*)} < 0$. By equations (2) and (3) and $r'_{UNEQ} - r'_{EQ} < 0$, we get the result in (17). □

Proposition 3 means that the marginal payoff of allocating unequally is larger than the value taken by the marginal payoff related to allocating equally. Moreover, the difference between marginal payoffs is larger than the relative importance of conformism. Here we obtain the following unexpected result.

The conformist aspect works against the stability of conventions. Indeed, if the payoff aspect is the only relevant informational source, the stability condition for interior conventions, requires that the marginal payoff of allocating equally evaluated at the population frequency, p, is lower than the marginal payoff of allocating unequally evaluated at this population frequency. That is, $\pi'_{EQ} < \pi'_{UNEQ}$. This condition is necessary, but it is not a sufficient condition when the conformist aspect acquires relevance. In such a case, the difference between payoffs needs be higher than this, $\pi'_{EQ} << \pi'_{UNEQ}$. Furthermore, there is a positive relationship between the needed difference between payoffs and the importance of the conformist aspect. Consider the case in which the conformist aspect is the only relevant informational source in the updating process. In this case, the whole interior conventions are unstable. Then, prenatal conventions are substitutive for postnatal conventions.

For the problem of the relationship between the postnatal and the prenatal gender conventions, the result entails the following. In a society where the conformist aspect is highly present, postnatal conventions are substituted by prenatal conventions faster than in societies of lower conformism. The reason is that there are more difficulties to correct exogenous perturbations with conformism.

5 Concluding remarks

In this paper we have modelled the evolution of postnatal gender-bias provided that prenatal gender-bias increases. For this purpose, we have developed a version of the conformism transmission models. In our version, we include individuals that switch to allocate survival resources equally as soon as they are able to control the family sex-composition.

Our model explains that certain environments lead to the existence of both, prenatal and postnatal gender-bias. Sadly, as we discuss in what follows, empirical evidence is compatible with the existence of those environments. For the discussion purposes, we focus on conditions for areas of the world where authors continually denounce the allocation of survival resources in favor of sons.

According to our model, the environmental features of these areas of the world determine the relationship between the evolution of prenatal and postnatal gender-biases. The conditions highlighted here refer to conformist features and payoff differentials. Our finds show that the use of the sex-selective abortion technology helps to discard the unequal allocation of survival resources provided that: (*i*) conformism is enough rooted in the society or (*ii*) the marginal payoff of allocating unequally fails to be enough large. Neither of these two conditions seem to be guaranteed.

On the one hand, the studies show that conformism is not the only relevant information that individuals use to allocate unequally. The aforementioned studies on the issue support that the differentials in economic value of men and women motivate the unequal allocation of the resources to offspring. That is, to some extent, the differential in economic value of males and females would explain the acquisition of postnatal behavioural traits. It implies that conformist might fail to be enough rooted in the society to drop out postnatal gender-bias.

On the other hand, as mentioned in the paper, the body of literature in this issue brings up to light some intuitions about the relationship between the slopes of the payoff functions (the one which captures the payoff of allocating equally, and the one which captures the payoff of allocating unequally). It is suggested that the scarcity of females would increase their economic value up to this value of males. It implies that there exists a period of time beyond which the payoff of allocating equally is larger than the payoff of allocating unequally. Meanwhile, the opposite relationship arises in the previous periods. In other words, the relationship between the payoff of allocating equally is supposed to be represented by an increasing function. Meanwhile the opposite relationship is though for the payoff of allocating unequally and people allocating unequally. It means that the marginal payoff of allocating unequally is likely to be large enough to support both types of gender inequality at the same time.

Considering the aforementioned features as the features of the society for which we aim to predict a pattern of behaviour, one concludes the following. Once a postnatal convention is established in this scenario, there are reasons to suspect that this becomes an stable convention. In such a case, one finds an additive relationship between both conventions. There the decrease of female births fails to reduce the neglected young females. The demographic outcome would be a dramatically increase of the number of missing young girls, instead of these numbers remaining constant over time.

This necessary condition for the existence of the stochastically stable equilibrium does not guarantee its existence, however. Therefore, the converse of the additive relationship might also apply. Indeed, the alarming effect may be shrunk by the conformist effects. Indeed, our model also shows that promoting conformism might help to erode female disadvantage. Postnatal conventions are substituted by prenatal conventions faster in conformist societies than in societies of lower conformism. The reason is that there are more difficulties to correct exogenous perturbations with conformism.

As mentioned above, if conformism were enough rooted in the society, then the postnatal convention could be weakened due to the evolution of the prenatal conventions (or by any other exogenous reason, such as the implementation of public policies). Therefore, our modelling strategy allows us to prove that the study of conformism merits further analysis when the focus is the research into female disadvantage. Future work is planned to empirically test the presence of conformism features in societies where preference for males is documented and, then, to accurately evaluate the implementation of public policies.

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