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LUIZA BETINA PETROLL RODRIGUES

ENSAIOS EM ECONOMIA DO TRABALHO COM DADOS DE GÊMEOS: GÊNERO, SALÁRIOS E MATERNIDADE NO BRASIL

ESSAYS IN LABOR ECONOMICS USING TWIN DATA: GENDER, WAGES, AND MOTHERHOOD IN BRAZIL

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Orientador: Prof. Dr. Daniel Oliveira Cajueiro

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Finally, I thank the Brazilian taxpayer, whose contributions through taxes sustain the Graduate Program of the Department of Economics. I hope that my work with twins contributes to the design of effective public policies that ultimately benefit these contributors.

RESUMO

Esta tese de doutorado reúne três artigos que utilizam dados inéditos de gêmeos brasileiros para investigar questões centrais da economia do trabalho.

O primeiro artigo apresenta a *TwinsBR*, a maior base de dados de gêmeos do mundo, construída a partir de registros administrativos brasileiros.

O segundo artigo utiliza pares de gêmeos de sexos opostos para estimar a diferença salarial entre homens e mulheres, controlando por fatores não observáveis como ambiente familiar e traços latentes.

O terceiro artigo analisa a penalidade da maternidade nos salários, comparando gêmeas com e sem filhos, e encontra um efeito menor do que o reportado por estudos anteriores. Ao explorar o potencial analítico de dados de gêmeos no contexto brasileiro, esta tese contribui com novas evidências empíricas sobre desigualdades de gênero.

Os resultados reforçam a importância de considerar fatores não observáveis em análises econômicas. Além disso, o trabalho abre espaço para novas abordagens metodológicas em pesquisas aplicadas.

ABSTRACT

This doctoral thesis comprises three articles that use novel data on Brazilian twins to investigate key issues in labor economics.

The first article introduces *TwinsBR*, the largest twin dataset ever constructed, based on Brazilian administrative records.

The second article estimates the gender wage gap by comparing opposite-sex twins, controlling for unobservable factors such as family background and latent traits.

The third article examines the motherhood wage penalty by comparing same-sex female twins with and without children, finding a smaller effect than previously reported in the literature. By exploring the analytical potential of twin data in the Brazilian context, this thesis provides new empirical evidence on gender disparities. The findings highlight the importance of accounting for unobservable factors in economic analysis. The work also opens space for new methodological approaches in applied research.

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SUMÁRIO

1. PAPER 1

TWINSBR: A NOVEL DATASET OF BRAZILIAN TWINS FOR APPLIED ECONOMIC ANALYSIS

Luiza Betina Petroll Rodrigues[1]

Department of Economics, University of Brasilia, Campus Universitario Darcy Ribeiro – FACE, Brasilia, DF 70910-900

ABSTRACT

This study presents TwinsBR, a novel large-scale dataset comprising 378,399 Brazilian multiples (primarily twins) born between 1986 and 2001 — likely the largest twin registry in the world. The dataset was constructed using an innovative identification strategy based on unique maternal identifiers within the Brazilian government ID system. TwinsBR includes formal employment records for these individuals as of December in each year from 2019 through 2022, supporting rich longitudinal analysis. This paper details the data sources, construction methodology, and provides descriptive statistics. Preliminary findings challenge established literature: male twins appear to earn slightly less than their singleton counterparts, a pattern not observed among females. TwinsBR offers a new empirical foundation for research in applied economics.
Keywords: database, labor data, twin studies.

RESUMO

Este estudo apresenta a TwinsBR, uma nova e extensa base de dados composta por 378.399 múltiplos brasileiros — predominantemente gêmeos — nascidos entre 1986 e 2001, constituindo provavelmente o maior registro de gêmeos do mundo. A base foi construída a partir de uma estratégia inovadora de identificação, baseada em identificadores maternos únicos no sistema de registros do governo brasileiro. A TwinsBR inclui informações de emprego formal desses indivíduos referentes ao mês de dezembro de cada ano, de 2019 a 2022, permitindo análises longitudinais ricas. Este artigo detalha as fontes de dados, a metodologia de construção e apresenta estatísticas descritivas. Resultados preliminares desafiam a literatura existente: gêmeos do sexo masculino tendem a receber salários ligeiramente inferiores aos de não gêmeos, padrão que não se observa entre mulheres. A TwinsBR oferece uma nova base empírica para pesquisas em economia aplicada.

Palavras-chave*: base de dados, dados de mercado de trabalho, estudo com gêmeos*

1. INTRODUCTION

Studies using twins have played a pivotal role across various disciplines over the past century. Twin studies in economics date back to the 1970s and are instrumental in identifying causal effects.

[1] luizabpr@gmail.com.

The construction of twin databases is essential for the progress of these studies. Panel databases, where variables are observed for the same pair of twins over multiple periods, are particularly valuable as they allow researchers to evaluate not only the differences between twins and how these differences evolve.

To address this gap, this study introduces a new twin panel comprising 378,399 individuals born in 188,263 multiple births between 1986 and 2001 in Brazil. Most of these individuals are twins, though the dataset also includes cases of triplets and quadruplets. For clarity, this dataset is referred to as the Brazilian Twin Registry, or "TwinsBR." The text details the data sources and construction methodology, presents descriptive statistics, and outlines initial empirical results.

The dataset includes nearly half of all twins born in Brazil during the study period, forming what appears to be the largest twin registry in the world. The extraction method does not show signs of introducing bias into the sample. Due to its scale and level of detail, the registry provides a valuable resource for future economic research in Brazil. Preliminary evidence indicates that younger cohorts of same-sex twins are less likely to engage in formal labor market activities compared to singletons, and that male twins tend to earn lower wages than their singleton counterparts.

This paper offers two contributions to empirical literature. First, it introduces a novel approach for identifying twins within the national ID system, relying exclusively on mothers without namesakes[2]. This method enables large-scale twin identification in Brazil without requiring direct contact or self-reporting. The main limitation of this approach lies in its inability to classify twins as monozygotic (MZ) or dizygotic (DZ)[3].

Second, the paper offers a detailed overview of twin presence in the formal Brazilian labor market, disaggregated by sex and twin type (same-sex or opposite-sex). It also provides an initial analysis of earnings differences between twins and singletons in December of the years 2019, 2020, 2021, and 2022.

The structure of the paper is as follows. This section introduces the study. Section 2 reviews the literature on twin datasets. Section 3 outlines the data sources and construction methods. Section 4 presents descriptive statistics and preliminary findings. Section 5

[2] A "namesake" refers to a person or thing that shares the same name as another. In the context of this article, identifying "women without namesake" is crucial because it ensures that the individuals being referenced do not share their names with others in the dataset. This uniqueness allows for accurate identification of mothers based on their names, as there is no ambiguity caused by duplicate names. For further details, please refer to the "Methodology" section.

[3] Except in the case of opposite-sex twins, who are always dizygotic. See Beiguelman (2008) for accessible technical details on the biology of twinning.

summarizes the key insights from the registry. An appendix provides supplementary descriptive details.

Throughout the study, males with a male co-twin (i.e., members of same-sex male twin pairs) are referred to as "M-M." The same categorization is applied to same-sex female twin pairs, denoted as "F-F." Individuals in opposite-sex twin pairs are identified as "M-F male" or "M-F female," respectively.

2. RELATED LITERATURE

Scholars have long been interested in twin studies, with early research rooted in the field of medicine. Notably, King Gustav III of Sweden, crowned in 1771, reportedly commissioned an experiment on identical twins to compare the health effects of tea and coffee (Afshari, 2017). Today, twin studies are instrumental in understanding the interplay between genetic and environmental factors in shaping behavior and other phenotypes. In addition, twin-based research plays a key role in studying causality, intergenerational transmission, and gene–environment interactions (Hagenbeek *et al*., 2023).

In economics, twin studies emerged in the 1970s, primarily to aid in identifying causal effects. One major strand exploits twin births as a natural experiment to examine how unplanned increases in family size affect outcomes such as parental labor supply and child development. Another strand compares monozygotic twins to isolate genetic influences, thereby assessing the relative importance of nurture versus nature (Bhalotra and Clarke, 2023)[4].

Several countries have established twin registers. Hur *et al*. (2019) documented 61 such registers across 25 countries. Table 1.1 updates this inventory for Latin America, adding the Cuban and Chilean datasets, as well as the new registry introduced in this study, the Brazilian Twin Panel (*TwinsBR*). The Cuban database is particularly noteworthy as it includes virtually all twins in the country (Marcheco-Teruel *et al*., 2013). Other Brazilian datasets were excluded due to their limited sample sizes or lack of individual identifiers (see Ferreira *et al*.,2016).

Table 1.1 shows that, prior to the creation of *TwinsBR*, Brazil already had an existing twin database, the “USP Twin Panel”. However, that dataset is significantly smaller, covering approximately 6,000 individuals, and contains very limited economic information, as it was developed primarily for health-related research. As a result, opportunities to conduct economic

[4] One important example in the economic literature is the use of twins to evaluate differences in earnings caused by differences in education (see Taubman,1976, and Card,2011). Another strand of the literature explores whether being born in a multiple birth affects earnings (see Huang *et al*.,2019, for a summary). However, to the best of my knowledge, no such studies have ever been conducted in South America.

analyses using twins in Brazil were scarce before the development of *TwinsBR*.

In addition to the national twin registries listed by Hur *et al*. (2019), many studies rely on purpose-built datasets. For example, Peter *et al*. (2018) used Swedish administrative data for singletons and merged it with information from the Swedish Twin Registry (STR). This methodology closely resembles the approach used to construct *TwinsBR*.

Table 1.1- Twin Registries in Latin America with samples larger than 2,000 individuals

Country	Brazil 1	Brazil 2	Chile	Cuba	Mexico
Name of the registry (*)	USP Twin Panel	TwinsBR (*)	TwinsCL (*)	TwinsCU (*)	TwinsMX
Major recruitment methods	University of São Paulo, media	National ID database + Formal job database	National test scores and Chilean birth registry	National ID database + door-to-door visits	Social media, public campaigns
ZYG	Q+DNA	None	None	Q	Q
Sample size	6,000	378,399	2,474	103,984	2,826
Academic performance information?	No	Only for those on formal labor market	Yes	No	No
Salary information?	No	Yes	No	No	Yes
Frequent updates?	Yes	Yes	No	No	Yes
Sources	Hur et al. (2019), Otta *et al*. (2019) and Otta (2024)	Author's elaboration.	Torche and Echevarr´ıa (2011)	Marcheco-Teruel *et al*. (2013)	Hur *et al*. (2019), Leon-Apodaca *et al*. (2019) and Garc´ıa-Vilchis *et al*. (2024)

Sources: Mentioned in the table. Notes: (i) Names marked by (*) were invented by me. (ii) ZYG = zygosity assessment methods. "Q" = questionnaire method; "Q+DNA" = questionnaire supplemented by DNA testing; "No" = zygosity was not assessed. (iii) Sample size refers to the number of people, not to the number of pairs of twins. The number of pairs is smaller. (iv) Another Mexican database cited by Hur *et al*. (2019), the "Mexico Twin Registry (MexTR)", was excluded from this compilation because it was under development in 2019 and I found no subsequent citations for it.

2.1. ZYGOSITY

A central limitation of *TwinsBR* lies in the absence of zygosity information. As opposite-sex twins are always dizygotic (DZ), the key question is the proportion of same-sex twins that are monozygotic (MZ, also known as "identical"). Data from other large-scale twin registries suggest that over 50% of same-sex twins are MZ (see column F of Table 1.2)[5].

If *TwinsBR* follows patterns similar to those observed in other panels, it is reasonable to

[5] The underlying theory remains a subject of debate and is beyond the scope of this study. This section compiles descriptive data from existing twin registries, without implying general patterns of monozygotic birth. For more on the methodology typically employed to estimate zygosity, including Weinberg's Differential Rule, see Fellman and Eriksson (2006).

infer that the average same- sex twin pair in the dataset shares more than 75% of their genetic material[6]. This high degree of genetic similarity, combined with a shared environment, reinforces the potential of *TwinsBR* for causal inference in economic research.

Table 1.2- Large Twin registries worldwide: percentage of twins by gender type and zygosity

Twin Registry	Twin Type	(A) % MZ	(B) % DZ	(C) % Unknown	(D=A+B+C) Overall proportion of twins (%)	(F=A/(A+B)) % of MZ
Australia	F-F	22	17	3	42	56.4
	M-M	16	15	2	33	51.6
	M-F	-	25	-	25	-
	Total	38	57	5	100	40.0
	Same-sex	38	32	5	75	**54.3**
Cuba	F-F	14.2	12.3	NA	26.5	53.7
	M-M	12.8	11.4	NA	24.3	52.8
	M-F	-	35.6	-	35.6	-
	Total	27.0	59.3	13.7	100	31.3
	Same-sex	27	23.7	13.7	50.8	**53.3**
Norway (1967-1991 cohort)	M-F	-	24.6	-	24.6	-
	Total	45.9	54.1	-	100	45.93
	Same-sex	45.9	29.9	-	75.4	**60.94**
East Flanders (Belgium)	F-F	17.7	14.0	2.6	34.3	55.72
	M-M	16.4	15.4	2.9	34.8	51.55
	M-F	-	30.9	-	30.9	-
	Total	34.1	60.4	5.5	100	36.08
	Same-sex	34.1	29.5	5.5	69.1	**53.63**

Sources: Hopper *et al*. (2013), Marcheco-Teruel *et al*. (2013), Nilsen *et al*. (2012) and Loos *et al*. (1998). Notes: NA=not available. "Rows labeled as 'Same-sex' refer to the sum of 'F-F' and 'M-M'." Please note that, except for the Cuban and the Belgian database, which includes almost every twin born, the percentages of twins by type and genre may reflect different recruitment methods.

3. METHODOLOGY

3.1. STUDY DESIGN

The foundation of *TwinsBR* is the Brazilian CPF database. The CPF (an acronym for "*Cadastro de Pessoas Físicas*", or "Natural Persons Register") serves as the primary identification number issued by the Brazilian Federal Revenue (Receita Federal do Brasil – RFB). In many ways, the CPF number is analogous to the US Social Security Number (SSN).

Due to its widespread use in public records and access to social programs[7], nearly the entire Brazilian population holds a CPF as of 2024. With approximately 280 million entries —

[6] Monozygotic twins share 100% of their genetic material, while dizygotic twins share, on average, 50%. For instance, if MZ twins constitute 53.27% of same-sex twins — as reported in the Cuban registry — the expected proportion of shared genetic material would be: 53.27% × 100% + (1 - 53.27%) × 50% = 76.6%.

[7] Many common activities in public life — such as holding a bank account, owning property or a vehicle, paying income tax, receiving certain types of social benefits or housing subsidies — require a CPF number.

including both living and deceased individuals (RFB, 2023) — the CPF database provides a robust source for research. It is therefore reasonable to assume that nearly all adults possess a CPF today, although this was not the case for children and adolescents during the 1980s and 1990s. Each record in the CPF database contains a unique identifier (the CPF number), along with the individual's name, date and place of birth, and the mother's name. Notably, the database lacks the mother's CPF number, which posed a challenge in identifying families due to the prevalence of namesakes. For example, "Maria da Silva" is a very common name in Brazil[8]. As a result, if two children born on the same day in the same city list "Maria da Silva" as their mother, one cannot confirm whether they are twins. To address this limitation, this study develops a specialized identification strategy.

The approach began with an age-based filter: women considered potential mothers in year *t* were those aged between 10 and 59 during that year[9]. Second, as exemplified in Table 1.3, each female in the CPF database was assessed to determine whether she fell within this age range in year *t*. The women in this age range represented the potential mothers for individuals born in that year. Third, only women without namesakes in the database were retained in the sample to minimize the likelihood of false-positive sibling or mother matches.

Table 1.3- Process of selecting potential mothers without a namesake out of the CPF database for year t and t+1 - example with hypothetical CPFs numbers and names of females

CPF number	**Full name**	**Gender**	**Year of birth**	**Year of death**	**Is potential mother**		**Has name equal to another potential mother (i.e., has namesake)?**	
					in t?	**in t+1?**	**in t?**	**in t+1?**
1	Leolinda Daltro	Female	t-11		Yes	Yes	No	No
2	Bibiana Terra Cambará	Female	t-9		No (too young)	Yes	—	Yes
3	Bibiana Terra Cambará	Female	t-36		Yes	Yes	No	Yes
4	Antonieta de Barros	Female	t-54	t-1	No (died before t)	No (died before t+1)	—	—
5	Aurélia Camargo	Female	t-20	t+1	Yes	Yes	No	No
6	Maria Capitolina Santiago	Female	t-30	t	Yes	No (died before t+1)	No	—
7	Anita Garibaldi	Female	t-71	t+2	No (too old)	No (too old)	—	—
8	Dandara dos Palmares	Female	t-45		Yes	Yes	Yes	No

[8] Maria is the most common name for women in Brazil, with a frequency of 11.7 million people (de Geografia e Estatística, 2016), and Silva is one of the most common family names (Monasterio, 2016).
[9] The age range for mothers was chosen because, according to Brazil (2023), between 1994 and 2001, no children were born alive in a multiple birth from a mother younger than 10 or older than 59 years. Data for earlier years are unavailable. This is a very conservative range: if we restricted the range to 14-45 years, we could identify more twins due to fewer female names being considered namesakes. However, this would increase the risk of attributing a child to the wrong woman.

9	Dandara dos Palmares	Female	t-59	t+2	Yes	No (too old)	Yes	—
10	Maria Quitéria Medeiros	Female	t-8	t+3	No (too young)	No (too young)	—	—

Source: author. Note: All CPFs number and names here are hypothetical. "—" refers to women who are not potential mothers in the year considered.

Note the importance of creating one separate list of potential mothers for each year *t*. Suppose two females named "Bibiana Terra Cambará" are alive in year *t*. One is 9 years old and the other is 36 (see Table 1.3). If the older Bibiana has a child in *t*, her identity as the child's mother can be uniquely determined, since she is the only eligible "Bibiana Terra Cambará" in that year. However, in $t + 1$, the younger the younger Bibiana turns 10 and becomes eligible as a potential mother. As a result, the name "Bibiana Terra Cambará" will no longer appear on the list of unique potential mothers in $t + 1$[10].

The fourth step is depicted in Table 1.4. For every Brazilian[11] born in year *t*, the mother's name was cross-checked against the list of unique potential mothers for that year. When the mother had no namesake in year *t*, her CPF number could be uniquely identified by linking the child to that specific mother. In other words, by linking a person named "X" to their mother without namesake, the mother's CPF number could be uniquely identified. This subset — individuals whose mothers could be reliably identified — represented approximately 44% of the total CPF entries for individuals born in year *t*.

Table 1.4- Process of selecting people born in year "t" that has a mother without namesake

CPF num-ber	Full name of son/daughter	Birth date	Mother's full name	Does the mother have a name equal to another potential mother (i.e., has namesake)?	Mother's CPF number
11	Guimarães Rosa	01/01/t	Francisca Rosa	Mother not found	—
12	Bolívar Cambará	01/01/t	Bibiana Terra Cambará	No	3
13	Leonor Cambará	01/01/t	Bibiana Terra Cambará	No	3
14	Pedro Camargo	01/01/t	Aurélia Camargo	No	5
15	Paulo Camargo	02/11/t	Aurélia Camargo	No	5
16	Ezequiel Santiago	01/01/t	Maria Capitolina Santiago	No	6
17	Aristogíton dos Palmares	01/01/t	Dandara dos Palmares	Yes	Not iden-tifiable
18	Harmódio dos Palmares	01/01/t	Dandara dos Palmares	Yes	Not iden-tifiable
19	Motumbo dos	10/10/t	Dandara dos Palmares	Yes	Not iden-

[10] Creating a single list of potential mothers without namesakes for the entire period between 1986 and 2001 would substantially reduce the sample size. On the other hand, it would allow us to capture information about siblings who are not twins. Returning to the example in the Table 1.3, if the older Bibiana had one child in 1986 and another in 1987, neither could be identified under this stricter criterion, as the name "Bibiana Terra Cambará" would not appear on the consolidated list.

[11] This approach excludes foreigners with CPF numbers, because their mothers typically do not have a CPF number.

	Palmares				tifiable
20	Machado de Assis	01/01/t	Not informed	—	—

Source: author. Notes: All CPFs number and names here are hypothetical. Please note that the information on column 5 comes from column 8 of Table 1.3.

The fifth step (Table 1.5) involved using the combination of "day of birth" and "mother's CPF" to identify instances of multiple births among these mothers. Subsequently, individuals were classified by birth type: "singletons" (those who are not multiples), "same-sex male twins" ("M-M"), "same-sex female twins" ("F-F"), "opposite-sex twins" ("M-F"), and "others" (pertaining to triplets, quadruplets, etc.).

Table 1.5 - Process of selecting people born in year "t" that has a mother without namesake

CPF number	**Full name of son/daughter**	**Birth date**	**Mother's CPF number**	**Birth type**
11	Guimarães Rosa	01/01/t	—	unknown
12	Bolívar Cambará	01/01/t	3	opposite-sex twins (M-F)
13	Leonor Cambará	01/01/t	3	opposite-sex twins (M-F)
14	Pedro Camargo	01/01/t	5	singleton
15	Paulo Camargo	02/11/t	5	singleton
16	Ezequiel Santiago	01/01/t	6	singleton
17	Aristogíton dos Palmares	01/01/t	Not identifiable	unknown
18	Harmódio dos Palmares	01/01/t	Not identifiable	unknown
19	Motumbo dos Palmares	10/10/t	Not identifiable	unknown
20	Machado de Assis	01/01/t	—	unknown

Source: author. Note: All CPFs number and names here are hypothetical.

3.2. SOURCES OF TYPE I ERROR: WRONGLY CLASSIFY CHILDREN AS BEING MULTIPLES

The approach developed is effective in capturing a large sample of multiples.

However, there is one scenario that could lead to the incorrect identification of children born on the same day as multiples: when one of the mothers does not have a CPF number. This situation occurred more frequently before the 1970s, which is why the data collection started in 1986. It became increasingly rare for individuals who survived until or after 2015[12].

Suppose that on a particular day in 1986: (i) child "cA" is born to mother "mA" who died shortly after, never having obtained a CPF number; (ii) child "cB" is born to mother "mB", who has the same name as "mA" but, unlike "mA", has a CPF number. In this case, the two children will be falsely regarded as twins (it will appear as though both are children of "mB").

This type of error is considered rare because it requires a specific combination of conditions: (i) exactly one woman with a certain name exists in the CPF database (if more than

[12] Having a CPF number is not mandatory, but very common in Brazil, as already explained.

one exists, she is excluded due to namesake); (ii) at least one namesake lacks a CPF; (iii) both women give birth on the same day; and (iv) both children appear in the CPF database.

3.3. SOURCES OF TYPE II ERROR: FAIL TO IDENTIFY A PAIR AS TWINS

The approach developed clearly fails to capture multiples born out of mothers with namesake, as already noted, as it lacks access to their CPF numbers and relies only on names.

It also fails when a mother's name has changed. Following the previous example, suppose Mrs. "Bibiana Terra Cambará" divorces after giving birth to twins and later appears in official records simply as "Bibiana Terra." This is the name that will be found when the researcher collects the data. However, the twins' original CPF records may still list their mother as "Bibiana Terra Cambará." If there are no other "Bibiana Terra Cambará" in the database, the twin pair will be disregarded because the mother could not be found.

Additionally, the method cannot detect twins separated through adoption. In such cases, the CPF database reflects the adoptive, not biological, mother. In the rare scenario where the siblings are adopted by different families, the approach cannot match them as twins.

These limitations are not concerning, as they exclude only a small fraction of twin pairs. There is no evidence that these exclusion mechanisms introduce systematic bias related to mothers' names or other observable characteristics.

3.4. LABOR DATA

The final step in constructing the database involved linking individuals whose mothers did not have a namesake to their formal labor market records.

Labor information was obtained from the "Novo CAGED" (New Caged). This dataset contains detailed monthly records of wages, admissions, and dismissals for formal employees, as reported by employers through the "eSocial" platform. Between 2018 and 2021, eSocial gradually replaced the RAIS and CAGED systems (MTE, 2023)[13]. Several studies have used data from Novo CAGED; see, for example, Alexandre and Silva (2023).

To ensure data quality, the analysis was restricted to individuals born between 1986 and 2001, who were therefore between 18 and 36 years old during the 2019–2022 period. Including older cohorts would increase the probability of encountering individuals whose mothers did not possess a CPF number, making linkage unfeasible. This limitation is particularly relevant for

[13] See Almeida (2020) for more details.

those born before 1980, when CPF coverage among women was significantly lower.

The dataset was filtered to include all formal workers in December of 2019, 2020, 2021, and 2022 who were born between 1986 and 2001 and whose mothers had no namesake, as defined in the previous section. The resulting samples for these years consisted of 8.4, 8.6, 9.8, and 9.6 million distinct workers, respectively.

After matching labor records with individuals from the CPF dataset, outliers were excluded. These included individuals with reported earnings below the legal minimum wage and those listed as working only one hour per week — patterns typically associated with reporting errors.

Once this process was completed, the construction of “TwinsBR” was finalized. The resulting unbalanced panel includes detailed employment records from Novo CAGED, as well as personal characteristics — such as twin status — derived from the CPF-based identification process. Appendix A lists the variables available in the TwinsBR database.

4. RESULTS

4.1. COMPARISON BETWEEN THE EXTRACTION AND THE BRAZILIAN POPULATION

The analysis of potential bias in the extraction process described above can be assessed through well-documented variables, such as the sex ratio at birth.

The natural human sex ratio at birth is approximately 107 to 103 males per 100 females, meaning that 50.7% to 51.7% of live births are typically male. Brazilian birth records follow this pattern, as shown in column B of Table 1.6.

Between 1986 and 2001, the average age for issuing a CPF number in Brazil was approximately 16 years. Since deaths up to the age of 14 are more common among males, the proportion of males among CPF holders is predicted to be slightly lower than in the live birth records. This is because some boys would have a live birth registration but die before obtaining a CPF number. This expectation is confirmed when comparing column B with column D of Table 1.6. This is why academic research on very young children in the 1980s and 1990s could not rely on the CPF number — only after 2017 did the average age at which a CPF was issued drop to less than one year old. On the other hand, research on adults has been conducted using the CPF number.

The question here is whether a sample of individuals born to mothers without namesakes

— used as the basis for identifying twins in the approach described in this paper — is similar to the CPF population. The answer appears to be affirmative: the percentage of men in this sample is extremely similar to that in the CPF population (compare columns D and L of Table 1.6. This pattern also holds for other metrics, such as the average age at CPF issuance. These findings suggest that the sample is broadly representative of the CPF population.

It is also important to determine whether the subsample of multiples extracted from this sample has characteristics similar to the global population of multiples. Again, the evidence suggests it does. First, the percentage of males among multiples, seen in column L of Table 1.6, is less than 50% both in my sample and in national registries of live births of multiples (Tabnet, 2024). This is also the case in other large twin databases (see Hopper *et al*. (2013) and Marcheco- Teruel *et al*. (2013), compiled in Table 1.2). However, the higher occurrence of female-female twins and lower occurrence of opposite-sex twin pairs is less common, mimicking the pattern seen in the Australian Twin Registry (Hopper *et al*., 2013).

The percentage of twins estimated in column M of Table 1.6 is similar to the percentages observed worldwide (Monden *et al*., 2021). From 1986 to 2001, this percentage rose from 1.36% to 1.73% (or 17.3 multiples per 1,000 live births). This increase may be due to several factors, including improved healthcare conditions (i.e., more twins were born alive and survived until they obtained a CPF number) and, to a lesser extent, the use of In Vitro Fertilization (IVF), which increases the likelihood of multiples. It may also be due to the reduction in the average age of issuing a CPF (from 18.4 years in 1986 to 13.1 years in 2001), thereby capturing more individuals who would otherwise have died without a CPF. Additionally, more women began obtaining a CPF after 1990, allowing them to be identified as mothers in the CPF database. None of these factors appear likely to introduce systematic biases in terms of genetics, educational outcomes, labor market behavior, or other traits commonly analyzed in twin studies.

The resulting sample of twins includes 378,399 multiples born between 1986 and 2001, forming 188,263 sets of siblings (twin pairs, triplets, etc.). This likely makes TwinsBR the largest standalone twin registry in the world. For comparison, the Swedish Twin Registry was recognized by Guinness World Records in 2015 as the largest in the world, with 194,000 individuals[14]. It also appears as the largest in Hur et al. (2019)[15]. TwinsBR is nearly twice as large.

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[14] 87,000 twin pairs according to Institute's website (2024).

[15] Consortia of twin registries cited by Hur *et al*. (2019), which combine registries from multiple countries, are not considered standalone registries in this comparison.

Table 1.6 - Live birth records compared with CPFs found in the CPF database – by year of birth

Year of Birth	**Live Birth Records**		**People in the CPF database**										
					CPFs whose mother didn't have a namesake								
								People born out of multiple births					
	(A) Number of births	**(B) % of males**	**(C) Number of people**	**(D) % of males**	**(E) Number of people**	**(F) % of males**	**(G=E/C) % of people whose mother didn't have a namesake**	**(H) Number of people**	**(I) Female Twins (F-F)**	**(J) Male Twins (M-M)**	**(K) Opposite- sex twins (M-F)**	**(L) % of males**	**(M=H/E) % of multiples**
1986	3,761,945	51.02	3,610,657	50.44	1,514,982	50.50	41.96	20,367	7,748	6,932	5,532	47.96	1.34
1987	3,700,113	51.05	3,580,100	50.43	1,515,427	50.49	42.33	20,269	7,470	7,004	5,620	48.81	1.34
1988	3,727,412	50.98	3,624,506	50.52	1,543,486	50.56	42.58	20,696	7,982	7,084	5,442	47.81	1,34
1989	3,616,551	51.03	3,548,079	50.53	1,521,517	50.58	42.88	21,378	8,006	7,372	5,848	48.47	1.41
1990	3,450,461	51.01	3,360,168	50.54	1,457,575	50.62	43.38	20,607	7,850	7,258	5,342	48.48	1.41
1991	3,477,817	51.12	3,394,646	50.59	1,480,802	50.66	43.62	21,991	8,304	7,718	5,786	48.61	1.49
1992	3,465,951	51.13	3,381,370	50.60	1,471,736	50.65	43.52	22,126	8,328	7,902	5,686	48.94	1.50
1993	3,593,057	51.13	3,492,052	50.61	1,527,707	50.68	43.75	22,930	8,400	8,354	5,910	49.73	1.50
1994	3,629,928	51.02	3,532,174	50.65	1,555,706	50.73	44.04	23,529	8,980	8,222	6,078	48.31	1.51
1995	3,651,089	51.11	3,579,538	50.69	1,574,526	50.71	43.99	25,344	9,714	8,962	6,286	48.33	1.61
1996	3,608,325	51.10	3,539,495	50.73	1,568,614	50.75	44.32	25,829	9,818	9,544	6,120	49.51	1.65
1997	3,619,719	51.01	3,548,089	50.68	1,587,011	50.71	44.73	26,855	10,218	9,742	6,470	49.15	1.69
1998	3,492,468	50.95	3,435,514	50.76	1,547,128	50.78	45.03	26,114	10,048	9,454	6,172	48.86	1.69
1999	3,565,885	51.18	3,519,415	50.90	1,600,062	50.94	45.46	27,202	10,258	9,882	6,664	49.27	1.70
2000	3,440,860	51.19	3,403,314	50.83	1,569,940	50.83	46.13	27,299	10,180	10,008	6,624	49.66	1.74
2001	3,247,727	51.19	3,223,658	50.84	1,498,367	50.91	46.48	25,863	9,972	9,464	6,000	49.02	1.73
Total	57,049,308	51.08	55,772,775	50.64	24,534,586	50.70	43.99	378,399	143,276	134,902	95,580	48.84	1.54

Source: de Geografia e Estatística (1986–2009) and author, based on RFB (2023). The information was extracted from the CPF database in November 4th, 2024.
Notes: [1] "Live Births Records" Refers to live birth records made until the children achieves 8 years of age. In the 80's and 90's, the real number of live births was probably 10% to 20% bigger than the live records made until this age. Please note that a person could have had its birth certificate issued when he or she was 9 years old (therefore would not be considered in column A) and after that have his/her CPF issued. So, it is possible to be considered in column C but not in column A (but this has become more and more rare). [2] CPFs that were null or canceled due to duplication were not considered for the calculations. [3] The sum of columns I, J and K is not equal to the value in column K because among the multiples there were 4,641 people who were higher-order multiples (triplets or more). These values were not shown in the table due to space constraints. [4] Column L refers to all males born alive out of multiple births divided by all people born alive out of multiple births. [5] Please note that a small percentage of the multiples of TwinsBR database is not alive anymore in 2024.

This meticulously curated initial sample for each year *t* offers several distinct advantages.

First, the extraction method is inherently unbiased, provided that the occurrence of feminine duplicate names does not systematically vary across socioeconomic strata or ethnic groups — a scenario deemed unlikely.

Second, individuals were not self-selected into the dataset[16], thereby reducing biases associated with cognitive ability, literacy, or social skills. This bias is particularly evident in the Mexican Twin database, as shown by Garcia-Vilchis *et al*. (2024). Consequently, the sample of individuals born to mothers without namesakes can be considered representative of the broader Brazilian population. Likewise, the subsample of multiples identified from these mothers can be accounted to represent the population of multiples in Brazil[17].

Third, the substantial size of the sample enables a wide range of estimations to be conducted.

4.2. PARTICIPATION OF TWINS IN THE FORMAL LABOR MARKET: DESCRIPTIVE STATISTICS

This section presents descriptive results regarding the participation rate in the formal labor market (PRFLM), comparing multiples with singletons.

Let $n_{y,t}$ represent the number of individuals born in year *t*, to mothers without namesakes, who were alive in December of year *y*. Among these, let $l_{y,t}$ denote the number of individuals formally employed in that same month. The PRFLM for year *y* is defined by the following expression:

$$\text{Participation Rate in the formal labor market (PRFLM)}_{y,t} = \frac{l_{y,t}}{n_{y,t}} \qquad (1.1)$$

The PRFLM, as calculated by Equation (1.1), can be defined by each gender and each group (singletons, female twins, male twins, opposite-sex twins etc.). Figure 1.1 displays the PRFLM for the full sample used in this study - that is, individuals born between 1986 and 2001

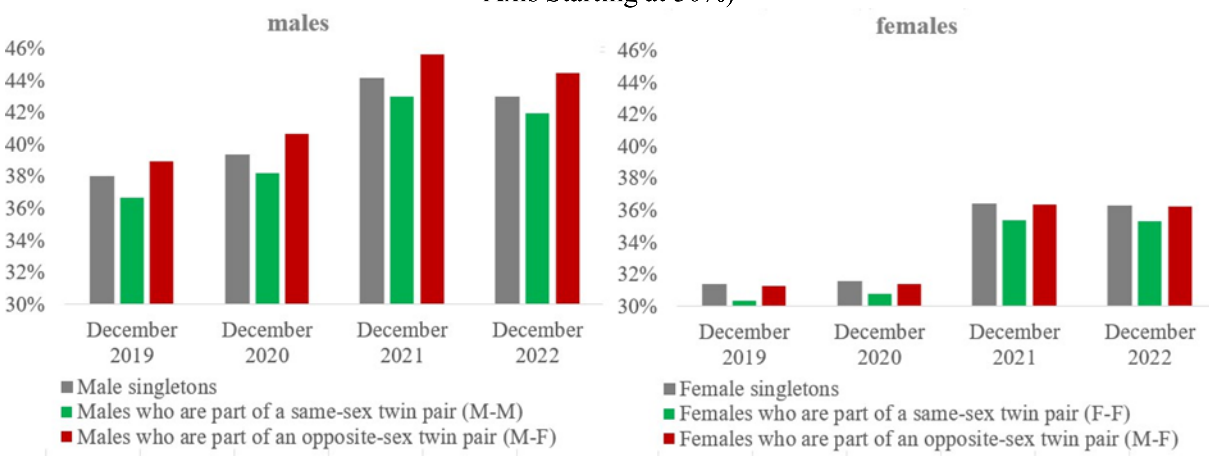
[16] This contrasts with cases like the sample in Taubman (1976), where participants responded to a recruitment letter. See Loos *et al*. (1998) for a discussion of biases in twin registries based on voluntary participation.
[17] Please note that the population of twins does not fully represent the population in Brazil, as twinning is more common among (a) Black women and older mothers in the case of natural conception, and (b) wealthier and older women in the case of assisted reproduction. However, between 1986 and 2001, assisted reproductive technologies were less prevalent than today, making factor (b) likely less relevant for this period.

to mothers without namesakes.

For males, Figure 1.1 indicates that the PRFLM is lower for “M-M twin males”. In contrast, “M-F twin males” exhibit substantially higher participation rates.

Among females, Figure 1.1 shows that twins — both F-F and M-F — have a lower PRFLM than female singletons.

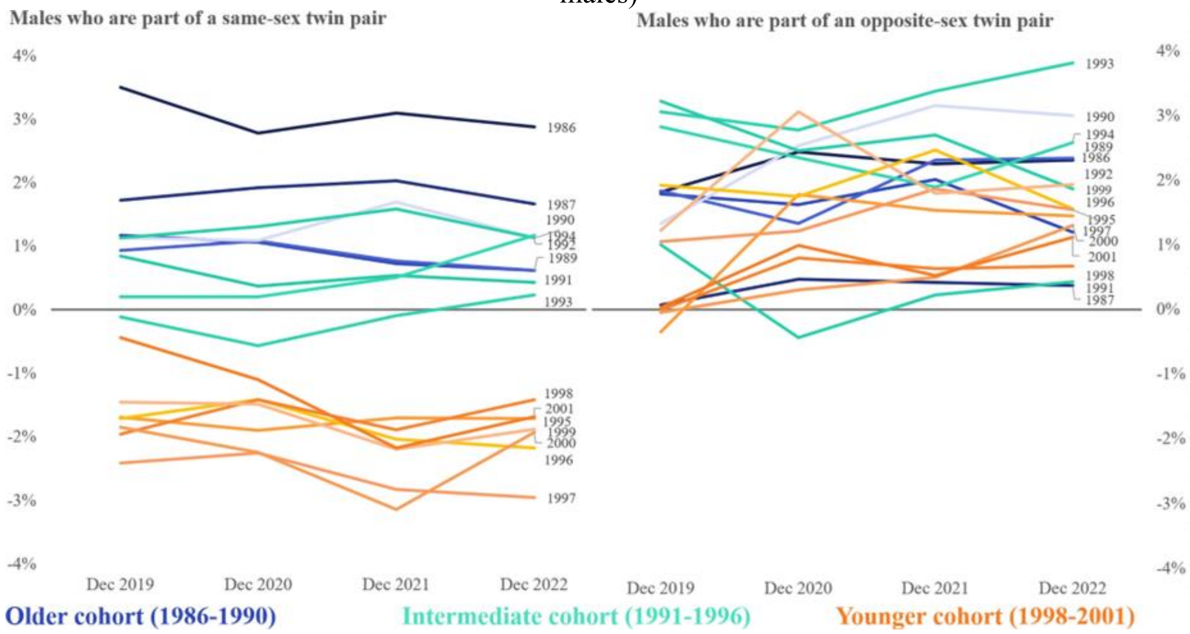
Figure 1.1 – Participation Rate in the formal labor market (PRFLM) according to type of birth (Vertical Axis Starting at 30%)



Source: author. (i) The classification of birth type was established in 2019; therefore, some twins whose co-twin died prior to that date may be classified as singletons. Due to the size of the sample, this is unlikely to affect the results. (ii) higher order multiples, such as triplets, were not included.

Figure 1.2 provides a detailed analysis of the PRFLM for males, highlighting the differences between multiples and singleton males. The figure shows that younger M-M” males were less likely to have a formal job compared to singleton males. Conversely, older M-M” males and all “M-F males” were more likely to be formally employed than singleton males across all reference periods.

Figure 1.2 – Difference between Participation Rate in the Formal Labor Market (PRFLM) of male twins and singleton males (negative values = PRFLM of male twins is lower than PRFLM of singleton males)

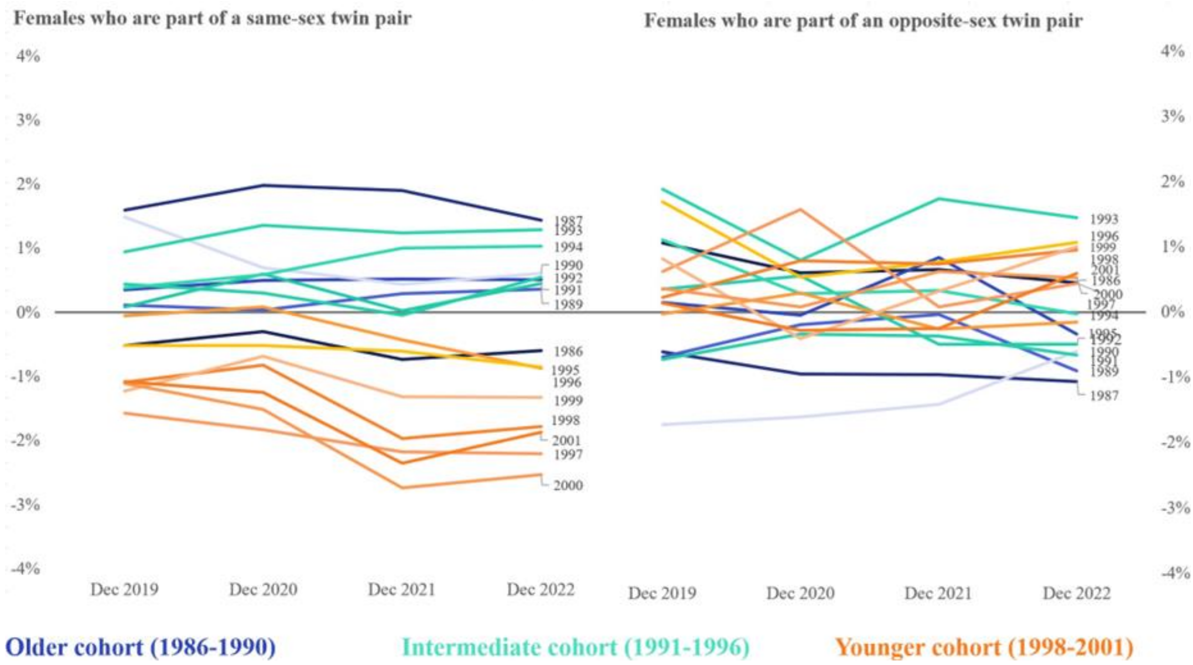


Source: Author's calculations. The same observations of Figure 1.1 apply.

Figure 1.3 conducts the same analysis for the female PRFLM. Similar to same-sex twin males, younger "F-F" were less likely to hold a formal job than singleton females. Also mirroring the pattern observed for older "M-M", older "F-F" were slightly more likely to be formally employed than singleton females across all periods. For M-F females", no distinct pattern was observed, indicating that their PRFLM closely resembles that of singleton females.

Overall, the differences in PRFLM between multiples and singletons appear to be more pronounced among males.

Figure 1.3 – Difference between participation Rate in the formal labor market (PRFLM) of female twins and singleton females (negative values = PRFLM of female twins is lower than PRFLM of singleton females)



Source: Author's calculations. The same observations of Figure 1.1 apply.

4.3. EARNINGS OF TWINS VERSUS SINGLETONS

In December 2019, 2020, 2021 and 2022, the average hourly wage of workers in the dataset stood at R$ 13.03, R$ 13.40, R$ 14.00 and $ 17.15, respectively, with substantial variation depending on gender, year of birth, and birth type. A detailed breakdown is available in Appendix B.

The following regression model estimates the conditional association between being a twin and hourly wages, controlling for a rich set of covariates:

$$\ln(hwage)_{i,t} = \beta_0 + \beta_1 \cdot \text{FF\_Twins} + \beta_2 \cdot \text{MM\_Twins} + \beta_3 \cdot \text{MF\_Twins} + \beta_4 \cdot \text{gender} + \beta_5 \cdot X_{i,t} \quad (1.2)$$

where $X_{i,t}$ is a matrix of covariates including educational level, tenure at the current job, age, age squared, race, number of contract hours, industry, state, log of per capita GDP of the employer's city, occupation sector, whether the employer is public or private, whether the employee's mother died in the given year, disability status, and number of job separations (voluntary or involuntary) in the previous three years. The dummy variables FF_twins, MM_twins, MF_twins indicate whether the individual is part of a pair of same-sex female twins, same-sex male twins, or opposite-sex twins, respectively. Since the regression includes a dummy variable for gender, each coefficient (β_1, β_2, β_3) estimates the percentage change in hourly wages relative to singleton individuals of the same gender, controlling for other characteristics.

Table 1.7 presents the results for the full sample, while Tables 1.8 and 1.9 show regressions disaggregated by gender. All models are statistically significant at the 0.1% level, as indicated by the F-statistic.

The most important results of the estimated regressions are:

- **Male twins** — both M-M and M-F males — earn less than singleton males. The "male twin penalty" on hourly wages ranges from 0.5% to 0.9%, depending on the year, and is statistically significant in most years (Table 1.8).
- **Female twins** (F-F and M-F females) earn approximately the same as singleton females. None of the coefficients are statistically significant in any year (Table 1.9).

The result for females is exactly the opposite of the findings presented in Huang *et al.* (2019), who used a sample of 3,000 pairs of individuals who are siblings (both twins and singletons) from the United States. Their empirical strategy controls for several confounding factors not used in the current study, including cognitive ability (as measured by the Peabody Picture Vocabulary Test), current school enrollment, marital status, number and age composition of children, and whether the employer provides health insurance or retirement benefits. Differences in sample composition, covariates, and country context likely contribute to the divergence in findings.

Table 1.7 - Regression Analysis of Hourly Wages: Coefficients for Twin Status Compared to Singletons

Explanatory dummy variables	**Dep. var.: log (hourly wage); sample: males and females**			
	Dec 2019	**Dec 2020**	**Dec 2021**	**Dec 2022**
Female twins (F-F)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.002)
Male twins (M-M)	-0.009*** (0.002)	-0.007*** (0.002)	-0.008*** (0.002)	-0.003 (0.002)
Opposite-sex twins (M-F)	-0.008*** (0.002)	-0.004** (0.002)	-0.005** (0.002)	-0.005** (0.003)
Observations	8,264,801	8,488,831	9,660,524	9,511,527
Adjusted R2	0.542	0.555	0.539	0.479
Res. Std. Error	0.398	0.408	0.415	0.483
degrees of freedom	8,264,617	8,488,647	9,660,340	9,511,343

Source: Author's calculation. *Notes:* (i) *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (ii) The table shows only the coefficient relevant for this study due to space constraints. Each regression also includes other variables - see Equation (1.2). All of them were significant at the 1% confidence level.

Table 1.8 - Regression Analysis of Male Hourly Wages: coefficients for Twin Status Compared to Singletons

Explanatory dummy variables	**Dep. var.: log (hourly wage); sample: males**			
	Dec 2019	**Dec 2020**	**Dec 2021**	**Dec 2022**
Male twins (M-M)	-0.007*** (0.002)	-0.006*** (0.002)	-0.007*** (0.002)	-0.001 (0.002)
Opposite-sex twins (M-F)	-0.009*** (0.003)	-0.005* (0.003)	-0.007** (0.003)	-0.009*** (0.003)
Observations	4,551,967	4,735,377	5,319,127	5,183,423
Adjusted R2	0.528	0.541	0.524	0.467
Res. Std. Error	0.404	0.413	0.423	0.490
degrees of freedom	4551786	4735196	5318946	5183242

Source: Author's calculations. *Notes:* Notes (i) and (ii) are the same as the Table 1.7, except for the fact that the dummy "gender" is not applicable here. (iii) The coefficients for the dummies "Male Twins" and "Opposite Sex Twins" should be interpreted as follows: they represent the percentage by which each of these groups earns more (or less) compared to the reference group (which consists of singleton males).

Table 1.9 - Regression Analysis of Female Hourly Wages: Coefficients for Twin Status Compared to Singletons

Explanatory dummy variables	**Dep. var.: log (hourly wage); sample: females**			
	Dec 2019	**Dec 2020**	**Dec 2021**	**Dec 2022**
Female twins (F-F)	-0.003 (0.002)	-0.003 (0.002)	-0.002 (0.002)	-0.002 (0.002)
Opposite-sex twins (M-F)	-0.005 (0.003)	-0.002 (0.003)	-0.001 (0.003)	-0.001 (0.004)
Observations	3,712,832	3,753,452	4,341,395	4,328,102
Adjusted R2	0.571	0.584	0.568	0.502
Res. Std. Error	0.385	0.396	0.400	0.471
degrees of freedom	3712651	3753271	4341214	4327921

Source: Author's calculations. *Notes:* Notes (i) and (ii) are the same as the Table 1.7, except for the fact that the dummy "gender" is not applicable here. (iii) The coefficients for the dummies "Female Twins" and "Opposite Sex Twins" should be interpreted as follows: they represent the percentage by which each of these groups earns more (or less) compared to the reference group (which consists of singleton females).

Further research is needed to deepen the understanding of how being a twin influences formal earnings and participation in the labor market. For instance, Huang *et al*. (2019) argue that comparisons should ideally be made between twins and closely spaced singletons — those with a sibling born within 12 months — rather than with all singletons. Future research should also examine whether the wage penalty observed among male twins stems from unobserved family dynamics, birth-related health factors, or labor market sorting mechanisms. The *TwinsBR* dataset provides a robust platform for advancing causal analyses on twinhood and labor market trajectories in the Brazilian context.

5. CONCLUSIONS

This study introduces *TwinsBR*, a novel and comprehensive dataset on Brazilian multiples born between 1986 and 2001. The methodology employed to identify and link twins does not appear to introduce sample bias, ensuring the reliability of the database for empirical analysis. The dataset is notably rich in detail, particularly concerning labor market outcomes in December of 2019, 2020, 2021, and 2022, making it a valuable asset for a broad range of economic and demographic research in Brazil.

Preliminary findings based on *TwinsBR* reveal relevant patterns. Descriptive analyses suggest noticeable differences in formal labor market participation between twins and singletons. Regression results indicate a small but consistent wage penalty for male twins relative to male singletons, a pattern not observed among females. These results contribute to an emerging literature that examines how twin status interacts with labor market dynamics, and they challenge findings from studies conducted in other countries.

Given the novelty of this dataset in the Brazilian context, further research is warranted. Future studies should consider more refined identification strategies, such as comparing twins to closely spaced siblings, and explore causal mechanisms underlying the observed patterns — particularly regarding gender asymmetries in wage outcomes. Additional investigations may also evaluate whether these findings extend to other labor market dimensions, such as occupational mobility, job quality, or informal employment.

By offering a large-scale, linked administrative dataset on twins, *TwinsBR* lays the groundwork for a new research agenda at the intersection of family structure, early-life conditions, and labor economics in Brazil.

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APPENDIX A – VARIABLES OF TWINSBR DATABASE

Table A.10 – Variables used in the regressions

Variable	Description
CPF number (1)(2)	Person's identification
Name	Person's full name
CPF issuance date	CPF issuance date
Gender (2)	Dummy: 0 for women, 1 for men.
Date of birth (2)	Date of birth
Age y (2)	Age in December of year y (in days)
Year of death (2)	Date of birth. Equals to NA if the person is alive.
Mother's CPF number (4)	Mother's identification number in the government database.
Mother's Date of birth (4)	Mother's Date of birth
Mother's name (2)	Mother's full name
Age of the mother at the birth (4)	Age of the mother at the birth
Year of mother's death (4)	informs the year of the mother's death. Equals to NA if the person is alive.
Mother died before 11 years old (4)	Dummy: 1 if the mother died before the son reached 11 years old.
Mother died in the current year y (4)	Dummy: 1 if the mother died in year y
Employers'id (1)	Company's identification number in the government database.
Legal nature of the company	Legal nature of the company (employer)
Industry (2)	Dummies for each industry: agriculture, extractive and manufacturing, construction, commerce, financial services and other services (including public administration).
Employers'city (1)	Company's city's quarters.
City population (3)	Number of inhabitants of the city where the person works
City's GDP per capita y (3)	GDP per capita of the city where the person works in year y
Admission date (1)	The date where the employee started to work in the current formal job
Educational attainment (1)	1 for no educational attainment, 2 for elementary school, etc. until 9 – masters or doctoral. Please note that this is different from years of schooling.
Race (1)	Dummies for race: white, black, brown, yellow or indigenous
y (1)	Year of reference for the salary
Type of disability	Informs the type of disability the employee has, if any
$Wage_y$ (1)	Total wage in R$, in nominal terms, in December of year yyyy, in a formal job
Contract hours y (1)	Number of hours that the employee works per week. Rows with 1 hour per week were excluded.
hwage yyyy	Wages paid for hours worked in December of year yyyy (in R$, in nominal terms). Calculated as $\left[wage_y\right] \div \left[4.3452 \cdot contracthours_y\right]$, due to the fact that a month has 4.34 weeks on average.
Tenure (1)	The length of time an employee has worked for their current employer, in months
Occupation (1)	Dummies for each of the 49 sub-major groups of CBO's occupations
N exits year y (1)	Number of dismissals from jobs in the last 3 years

Source: variables (1) are informed by the employer and extracted from Ministério do Trabalho e Emprego (MTE) (2023). Variables (2) are taken or inferred from Receita Federal do Brasil (2023)'s databases; variables (3) are from IBGE. (4) Inferred according to the methodology in section 3.1.

APPENDIX B. AVERAGE HOURLY WAGE OF INDIVIDUALS (CPFS) WHOSE MOTHER DIDN'T HAVE A NAMESAKE (IN R$, NOMINAL)

Year of birth	Type of multiple (1)	Dec2019		Dec2020		Dec2021		Dec2022	
		Male	Female	Male	Female	Male	Female	Male	Female
1986	Singleton	19.56	17.87	20.13	18.77	21.02	19.27	25.03	22.72
	SS twins	19.75	17.60	20.26	18.75	20.50	19.33	25.08	21.88
	OS twins	18.24	16.62	19.07	18.36	20.12	18.39	23.67	22.24
	Other (2)	21.49	21.98	22.10	20.16	23.08	19.98	40.50	21.95
1987	Singleton	18.59	17.22	19.14	18.07	20.04	18.60	23.98	22.12
	SS twins	18.21	16.64	18.55	17.55	19.57	18.34	23.56	21.37
	OS twins	17.43	16.16	17.86	17.29	18.34	17.42	21.78	20.91
	Other (2)	25.11	16.14	24.45	15.86	23.00	17.56	27.26	18.82
1988	Singleton	17.51	16.33	18.06	17.20	19.02	17.78	22.88	21.18
	SS twins	18.04	16.18	18.42	17.12	19.03	17.55	23.67	20.76
	OS twins	16.04	15.69	16.92	16.63	17.80	17.00	20.58	20.00
	Other (2)	24.22	14.55	23.93	14.12	29.70	16.23	35.14	17.64
1989	Singleton	16.48	15.50	17.06	16.36	18.04	17.02	21.72	20.42
	SS twins	15.80	15.66	16.42	16.25	17.35	16.56	21.30	20.19
	OS twins	15.52	14.75	15.87	15.56	16.88	16.14	19.40	19.25
	Other (2)	20.32	16.63	20.78	17.74	28.56	19.41	38.83	20.38
1990	Singleton	15.55	14.79	16.16	15.63	17.21	16.39	20.90	19.86
	SS twins	16.04	14.37	16.83	15.42	18.24	15.88	22.20	19.02
	OS twins	14.78	14.23	15.47	14.54	16.39	15.58	20.22	18.43
	Other (2)	20.15	19.22	21.96	22.44	25.72	26.43	28.53	25.16
1991	Singleton	14.42	13.76	15.04	14.58	16.15	15.45	19.72	18.85
	SS twins	14.58	14.05	14.84	14.94	15.89	15.55	19.75	18.57
	OS twins	13.53	12.40	13.86	13.31	15.19	14.77	17.53	16.58
	Other (2)	11.83	20.89	11.70	21.69	13.01	21.86	14.25	31.76
1992	Singleton	13.29	12.64	13.88	13.48	14.96	14.39	18.38	17.78
	SS twins	12.85	12.39	13.38	13.27	14.41	14.23	18.54	17.32
	OS twins	12.85	11.64	13.29	12.20	14.30	13.73	17.01	16.39
	Other (2)	13.45	12.47	13.44	13.32	13.83	14.53	14.80	16.71
1993	Singleton	12.22	11.70	12.83	12.49	13.93	13.42	17.15	16.66
	SS twins	12.51	11.57	12.98	12.38	14.27	13.22	17.58	16.36
	OS twins	12.45	11.79	13.13	12.54	14.48	13.50	17.10	17.14
	Other (2)	14.76	19.97	15.69	19.87	17.88	19.20	20.80	21.85
1994	Singleton	11.31	10.85	11.96	11.63	13.06	12.63	16.24	15.79
	SS twins	11.17	11.05	11.74	11.88	12.83	12.78	15.99	16.11
	OS twins	10.75	10.64	11.50	11.42	12.57	12.30	14.74	16.02
	Other (2)	11.77	10.74	15.15	12.57	17.42	15.10	20.19	17.63
1995	Singleton	10.48	10.03	11.10	10.81	12.24	11.85	15.35	14.92
	SS twins	10.36	10.02	11.03	10.75	12.21	11.81	15.20	14.78
	OS twins	10.21	10.53	10.85	11.03	12.07	11.93	14.97	13.97
	Other (2)	12.33	12.50	14.91	13.09	15.35	15.56	19.43	18.99
1996	Singleton	9.74	9.30	10.35	9.97	11.45	11.04	14.40	13.94
	SS twins	9.79	9.34	10.32	9.92	11.45	11.03	14.47	14.03
	OS twins	9.64	9.38	10.52	10.15	11.18	10.93	14.11	13.35
	Other (2)	10.10	10.05	10.33	12.00	12.14	13.35	18.82	17.30
1997	Singleton	9.00	8.59	9.49	9.13	10.52	10.17	13.35	12.99
	SS twins	9.27	8.60	9.64	9.00	10.57	10.12	13.47	13.38

Year of birth	Type of multiple (1)	Dec2019		Dec2020		Dec2021		Dec2022	
		Male	Female	Male	Female	Male	Female	Male	Female
	OS twins	9.18	8.64	9.47	9.34	10.68	10.60	14.08	12.96
	Other (2)	8.96	9.00	11.39	9.95	13.55	12.21	16.18	16.80
1998	Singleton	8.41	8.13	8.82	8.45	9.76	9.36	12.35	11.99
	SS twins	8.22	8.09	8.66	8.35	9.58	9.36	11.81	11.71
	OS twins	8.45	8.11	8.71	8.50	9.60	9.88	11.64	13.32
	Other (2)	7.92	8.63	8.18	9.44	10.63	10.23	16.62	14.43
1999	Singleton	8.04	7.77	8.45	7.90	9.21	8.63	11.38	11.02
	SS twins	8.05	7.60	8.52	7.76	9.19	8.38	11.97	10.84
	OS twins	8.37	7.66	8.47	8.06	9.14	8.59	11.37	12.15
	Other (2)	8.19	7.79	8.86	7.44	9.10	8.55	11.46	11.93
2000	Singleton	7.65	7.49	7.94	7.53	8.57	8.10	10.29	10.05
	SS twins	7.58	7.52	7.86	7.62	8.54	8.12	10.16	9.84
	OS twins	7.85	7.45	8.02	7.63	8.62	8.03	10.50	9.75
	Other (2)	7.35	7.00	8.04	7.75	9.43	7.93	11.83	9.61
2001	Singleton	7.31	7.23	7.30	7.10	7.94	7.66	9.30	9.12
	SS twins	7.29	7.10	7.13	7.22	7.89	7.71	9.27	8.95
	OS twins	7.66	7.08	7.71	6.90	7.99	7.54	9.49	9.36
	Other (2)	7.12	8.52	6.53	7.30	7.56	7.96	8.91	10.78

Source: author's calculations. Notes: (1) "Type of multiple" is a classification based on the situation in 2019. Some people may have been born a twin, but his/her co-twin may have died without ever getting a CPF. These individuals are classified as singletons. However, due to the size of the sample, this is unlikely to change the average. (2) "Other" refers to higher-order multiples (like triplets). (3) Outliers such as "Employees reported as having worked 1 hour per week" or "earnings above R$ 2,500 per hour" were excluded from all calculations.

2. PAPER 2

GENDER PAY GAP AND THE ROLE OF UNOBSERVABLES: A TWIN-BASED APPROACH

Luiza Betina Petroll Rodrigues[18]

Department of Economics, University of Brasília, Campus Universitário Darcy Ribeiro – FACE, Brasília, DF, 70910-900.

ABSTRACT

How large is the gender pay gap — really? Much of the literature and media coverage focuses on average wage differences between men and women, often comparing individuals with very different backgrounds and job characteristics. This study takes a different approach by focusing on individuals with highly comparable profiles. Using a novel empirical strategy, it compares wage differences between opposite-sex twins and randomly matched male-female pairs with the same date and region of birth in Brazil. Among workers in the same occupation and industry, the unexplained gender gap disappears for twins but remains positive for random pairs. These findings suggest that controlling for unobservable characteristics — such as family background and latent traits — substantially reduces gender wage disparities. The analysis draws on the world's largest twin dataset (TwinsBR), with over 8,000 opposite-sex twin pairs and 1.5 million randomly matched pairs, and employs decomposition techniques, matching methods, and fixed-effects models. Although based on a young cohort, the results challenge conventional interpretations of the unexplained gender gap and underscore the importance of accounting for unobserved heterogeneity in wage analyses.

Keywords*:* Gender gap, Twins, Occupation.

RESUMO

Qual é, de fato, a magnitude da diferença salarial entre homens e mulheres? Grande parte da literatura e da cobertura da mídia concentra-se nas diferenças salariais médias entre os sexos, frequentemente comparando indivíduos com perfis bastante distintos em termos de histórico e características ocupacionais. Este estudo adota uma abordagem diferente ao focar em indivíduos com perfis altamente comparáveis. Utilizando uma estratégia empírica inovadora, compara as diferenças salariais entre gêmeos de sexos opostos e pares aleatórios de homens e mulheres com mesma data e região de nascimento no Brasil. Entre trabalhadores na mesma ocupação e setor, a diferença salarial não explicada desaparece entre os gêmeos, mas permanece positiva nos pares aleatórios. Esses resultados sugerem que controlar por características não observáveis — como histórico familiar e traços latentes — reduz substancialmente as disparidades salariais de gênero. A análise utiliza o maior banco de dados de gêmeos do mundo (TwinsBR), com mais de 8.000 pares de gêmeos de sexos opostos e 1,5 milhão de pares aleatórios, e emprega técnicas de decomposição, métodos de pareamento (matching) e modelos com efeitos fixos. Embora baseada em uma amostra jovem, a pesquisa desafia interpretações

[18] Corresponding author: luizabpr@gmail.com

convencionais sobre a diferença salarial não explicada e destaca a importância de considerar a heterogeneidade não observada em análises salariais.

Palavras-chave*: Desigualdade de gênero, Gêmeos, Ocupação.*

1. INTRODUCTION

Wage differentials remain a perpetual concern within the field of Economics, and the gender earnings gap (GG) is an especially pressing topic.GG varies substantially across occupations, age groups, and countries. A thorough examination across these dimensions is essential, not only for academic purposes but also to inform public policy.

This study leverages a new and extensive dataset of Brazilian twins: “TwinsBr” (Rodrigues, 2025). The sample includes a large number of individuals born between 1986 and 2001, along with their presence as employees in the formal market during at least one of the four months analyzed: December 2019, 2020, 2021, and 2022.

This work uses TwinsBR to analyze the hourly earnings differences between opposite-sex twins, compares them to earnings differences between artificially matched male-female pairs born on the same date and in the same region (“fake twins”), and evaluates the gender pay gap in both groups.

A key concept in this analysis is the Unexplained Gender Pay Gap (UGP), defined as the portion of the gender wage gap that remains after accounting for observable endowments such as education, experience, and region. This measure is often interpreted as a residual difference, potentially reflecting discrimination or unobserved factors. Is UGP smaller among opposite-sex twins?

Results show that while the gender pay gap varies widely depending on the method of calculation, it is safe to say that the gender gap is not smaller within opposite-sex twins. However, among opposite-sex twins with common support, the UGP is effectively zero. In contrast, it remains positive among fake twins. This means that we can explain wage disparities among twins based on their different endowments, such as occupation, industry and education level, but the same cannot be said about random pairs. These findings reinforce the importance of using genetically and environmentally matched samples to isolate sources of wage inequality.

This paper offers two contributions to the empirical literature. First, to my knowledge, this study stands as the inaugural examination of gender earnings gap using opposite-sex twins.

By focusing on these pairs, the study controls for unobserved characteristics, such as family background and early life environment, that typically confound gender gap analyses. This study thus provides a rare link between the literature on wage differences on twins (particularly focused on same-sex-twins), like Miller *et al*. (1995) and the literature on gender pay gap, like Corley *et al*. (2006).

Second, this work distinguishes itself as one of the rare twin studies that benchmarks its findings against those derived from a random sample. This comparative analysis aims to validate the efficacy and insights derived from the twin study.

The findings of this text are significant for several reasons. First, it highlights the importance of controlling for non-observable factors, such as family environment and early life conditions, which are often overlooked in traditional analyses. Second, it suggests that part of the unexplained wage disparities between men and women can be attributed to these unobservable variables. Finally, the study underscores the utility of using twin studies to gain deeper insights into the mechanisms driving the gender pay gap, offering a robust methodological contribution to the field.

By providing a clearer understanding of the factors contributing to wage disparities, this research has important implications for policy-making aimed at reducing the gender pay gap. It suggests that interventions targeting early life conditions and family environments could be effective in mitigating these disparities.

This paper proceeds as follows. Section 2 reviews the literature on the gender pay gap and wage differences among twins, and discusses the methodological advantages and limitations of twin studies. Section 3 outlines the empirical strategy. Section 4 describes the process of building the dataset and Section 5 presents the findings. Section 6 summarizes and concludes the paper. Section 7 points out some limitations of the work.

Throughout, opposite-sex sibling pairs are referred to as “OS”. Opposite-sex twins (“OST”), a subgroup of OS, are pairs composed of an “OST female” and her co-twin brother, the “OST male”. Same-sex siblings and same-sex twins, on the other hand, will be referred to as SS and SST.

2. RELATED LITERATURE

This section reviews the main strands of the literature relevant to this work. It begins by clarifying the different definitions used to measure the gender earnings gap. It then discusses the main methodologies of calculation employed in the literature, including their limitations and recent innovations. Afterwards, it presents the emerging literature that uses opposite-sex siblings — especially twins — as a strategy to control for unobserved family background and genetic traits, and discusses the extent to which these samples are appropriate for estimating gender-related differences in labor market outcomes.

Finally, this section situates the present research within the broader Brazilian literature on gender disparities in the labor market, which has documented persistent wage gaps and explored various explanatory channels.

2.1. DEFINITIONS

The gender gap refers to the persistent empirical finding that women earn less than men. However, the literature does not rely on a single measure to quantify this disparity. Instead, several definitions coexist — each using different denominators and functional forms — which can lead to confusion and limit comparability across studies. Clarifying these definitions is essential before turning to the empirical methods used to estimate the gap.

Goldin (2014) uses the ratio of women's hourly earnings to men's:

$$Gender\ pay\ ratio\ (GR) = \frac{Average\ hourly\ wage\ of\ woman}{Average\ hourly\ wage\ of\ man} = \frac{\overline{w^F}}{\overline{w^M}} \tag{2.1}$$

ILO (2018) defines the unadjusted or “raw” gender gap as the difference between the average earnings of males and females. When comparing average hourly wages, we have:

$$Raw\ Gender\ Gap\ (RGG) = \frac{\overline{w^M} - \overline{w^F}}{\overline{w^M}} = \frac{\overline{Hourly\ wage\ difference (\Delta w)}}{\overline{w^M}} = 1 - GR \tag{2.2}$$

This variable is the main interest of most of the papers — though I myself believe that the numerator, $\overline{\Delta w}$, is easier to understand - because it is expressed in monetary units – and just as important.

Oaxaca (1973) in turn, used the female wage as denominator (therefore, his measure usually results in a higher gender gap figure). This choice is useful because it can be directly transformed into a logarithmic form. However, it is less common:

$$Oaxaca'sGG\ (OGG) = \frac{\overline{w^M} - \overline{w^F}}{\overline{w^F}} = \frac{\overline{(\Delta w)}}{\overline{w^F}} = \frac{1 - GR}{GR} = \frac{RGG}{1 - RGG}$$
$$\Rightarrow \ln(OGG + 1) = \ln\left(\overline{w^M}\right) - \ln\left(\overline{w^F}\right) \quad (2.3)$$

The fourth definition is a gender gap calculated on a pair-by-pair basis between similar workers. To do this, a pair "i" of a man and woman with common support is compared:

$$GG\ calculated\ on\ a\ pair - by - pair\ basis\ (PGG_i) = \frac{w_i^M - w_i^F}{w_i^M} = \frac{\Delta w_i}{\overline{w_i^M}} \quad (2.4)$$

The different measures of gender gap lead to different results. Suppose a case in which men earn R$ 4 and women receive R$ 1. In this scenario, GR would be 25%; RGG and PGG would be 75% and OGG would be 300%. This is important because GR, RGG and PGG are especially sensitive to low salaries of men (the denominator), which produce outliers. OGG, on the other hand, is sensitive to low salaries of women.

From here on, this work will use the terms "raw gender gap" (RGP) and "pair gender gap" (PGG), as calculated by Equations (2.2) and (2.4), respectively, to denote the earnings disparities, for the sake of brevity. The term "gender gap" is used generically, when the formula is not clear or explicit, to refer to the wage difference between men and women.

2.2. LITERATURE ON GENDER GAP AND CRITICISM

The literature on gender wage differences — also referred to as the gender pay gap or gender earnings gap — is extensive and primarily concerned with identifying the "unexplained gender pay gap" (UGP), meaning the portion of the difference that remains after accounting for productivity-related factors. In this context, two methodological approaches are most commonly used.

The main methodological approach to investigate wage differences is Blinder (1973)'s and Oaxaca (1973)'s – hereafter BO[19]. This method is considered the standard procedure to investigate wage differences (Weichselbaumer and Winter-Ebmer, 2005). The BO methodology compares averages of male and female earnings (Ñopo, 2008).

In a seminal work, Weichselbaumer and Winter-Ebmer (2005) made a meta-analysis of 263 econometric papers which investigated the gender pay gap in 63 countries during the time period between the 1960's to the 1990's, all of them using some variation of the BO methodology. According to this work, data restrictions impact the calculated gender pay gap heavily. The authors imply that choosing a non-restricted sample would be more important than the choice of the econometric methods.

While the contribution of these works on gender wage differences mentioned by Weichselbaumer and Winter-Ebmer (2005) is indisputable, they all suffer from important criticisms20. One important criticism is that yes, methodology matters, especially when it comes to the model specification and hypothesis. As outlined by Ospino et al. (2010), the BO model is an OLS model, which assumes normality of residuals and a random sample – but many works fail to report normality tests (see Urquidi et al., 2023, and Fogel and Modenesi, 2024, just to mention a few). Additionally, Ospino et al. (2010) detail that estimates of wages equations often contain a sample selection bias, which arises when non-observed factors that influence the likelihood of participation are correlated with non-observed ones affecting wage. This could produce wrong conclusions about the degree of wage discrimination against women.

The second methodological approach to investigate wage differences is Ñopo (2008)'s. The author made a strong and important critique of the BO methodology and proposed the use of matching, a non-parametric tool, to fix the problem of gender differences in the supports.

As it turns out, different methodologies can lead to different conclusions about the gender gap. Changing aggregate data for microdata (to enforce comparability between men and women), "together with a more flexible specification of the wage equation", may reduce the gender gap up to 39% in BO estimates. Also, semi-parametric matching yields estimates that are up to 50% smaller to BO estimates (Strittmatter and Wunsch,2021), and the use of machine learning offers very different insights about the distribution of the gender wage gap

[19] Some works name this method "KOB" to include the contribution of Mrs. Evelyn Kitagawa. However, Oaxaca and Sierminska (2023) warns that BO and Kitagawa approaches "are framed quite differently and do not overlap except in a special set of circumstances". As this is not the main topic here, I opted for the conservative terminology.

[20] See Ospino *et al*. (2010) for a nice summary of criticism and proposed methodological improvements.

(Bonaccolto-Töpfer and Briel, 2022).

However, all the methodologies cited above remain subject to the criticism that unobserved characteristics of men and women — such as parental attention and encouragement during childhood, preschool quality, home nutrition, and the quality of the home study environment — may influence future occupational choices and productivity, potentially biasing the interpretation of the estimated coefficients.

Blinder (1973) raised concerns about excluding family background variables, suggesting that these factors likely play a crucial role in shaping educational and occupational outcomes, even if they do not directly influence wage levels. This body of research offers a framework to assess the actual significance of family background and shared genetics in determining the economic returns to education.

In another area of academic literature, works that analyze the differences in economic outcomes between opposite- sex siblings try to partially address the problem of unobserved characteristics. Opposite-sex siblings share part of the genetic information and a similar family background. The similarities are greater for a subsample of opposite-sex siblings: the opposite-sex twins (OST)[21]: OST "share more genetic information, on top of identical prenatal care, than two randomly chosen students of opposite gender" (Bharadwaj *et al.*,2016).

2.3. PROBLEMS WITH OPPOSITE-SEX-TWIN STUDIES THAT MAY AFFECT WAGE ESTIMATES

The problems of twin studies are well known, so I will not dwell on this point more than necessary. Taubman (1976) (and others after him) have already made a good summary of possible problems, like the fact that twins may not represent the entire population. In this section, I will address only the problems that may affect works that use OST to analyze wages. After all, if opposite-sex twins wages are much different from the rest of the population, calculating the gender gap with this sample would lead to different conclusions.

In this realm, three important issues emerge. The first is that wages may not be neutral

[21] Please note that OST are always dyzigotic (DZ). OST share part of the genetic material, like all brothers do, but are never "identical".

to prenatal conditions: birth weight[22] and exposure to prenatal testosterone (EPT)[23], for example, may affect future economic outcomes. Second, wages may not be neutral to family composition: having a brother or a sister, or more than one, may affect your level of competitiveness, increase your shared network and many other positive or negative effects that may affect wages (Rao and Chatterjee, 2018), and Cools and Patacchini,2019). Third, wages may not be neutral to parental preferences. It is out of the scope of this work to define which of these effects is greater; here I am interested in the total effect, that is, the total impact of being an OST on earnings.

The following subsection shows that most of academic work have found that there's no difference between the wages of OST and other groups, or that this difference is small (close to 1%).

2.4. STUDIES ON WAGES USING OPPOSITE-SEX SIBLINGS AND TWINS

Economic studies that use twins to analyze wage differences typically aim to isolate the causal effect of specific variables on earnings. By comparing twins, researchers can control for unobservable factors such as family background. Gender is rarely the central issue, so the literature is highly focused on using samples of same-sex twins (SST)[24].

However, some papers use a database of opposite-sex siblings or twins to analyze wages. Huang *et al*. (2019) made a comprehensive summary of this literature. These studies primarily investigated the impact of having an opposite-sex co-twin in the job market, and the (contradictory) results calculated whether the female twin earned more or less than a singleton female, or whether the male twin earned more or less than a singleton male. However, none of

[22] Birth weight may affect future salaries (Behrman and Rosenzweig,2001), and twins are expected to be born lighter than singletons. There is also evidence that birth size and gestational age differ for OST and SS: Jelenkovic *et al*. (2018) used a large sample and concluded that OST males are heavier and longer at birth than SS males. However, these differences are modest and partly explained by a longer gestation in the case of OST.

[23] According to Gielen *et al*. (2016), testosterone "is believed to transfer from males to their littermates in placental mammals". Therefore, it is believed that EPT may affect females in the womb. However, the effects of this exposure of prenatal testosterone on earnings are far from consensual, and the exposure is not exclusive for OST. Nye *et al*. (2017) used a sample of singletons and found that higher prenatal testosterone (measured by the relative length of the second to the fourth finger) leads to greater rewards in the labor market (for both men and women).

[24] See for example the influential work of Bound and Solon (1999), who revised the literature that tries to estimate the return to schooling using samples of twins. See also Bingley *et al*. (2009), who estimated the returns to schooling based on a large sample of Danish twins and discussed the downward bias of OLS and fixed-effect estimators. Another influential work, Taubman (1976), used a sample of MZ and DZ male twins to evaluate the determinants of the variance of the log of earnings.

these studies calculated the gender pay gap within twin pairs by directly comparing each female twin to her male co-twin. Moreover, no research to date has explored the gender pay gap using opposite-sex twins — either in developed or developing countries.

Gielen et al. (2016), Huang et al. (2019), Peter et al. (2018), and Rodrigues (2025) compare the wages of OSTs with those of SSTs, CSSs, and the general workforce. As shown in Table 2.1, wage differences across these groups are either small or statistically insignificant. These findings suggest that any potential bias affecting OSTs is minimal. This supports the use of OSTs as a valid sample for analyzing the gender wage gap in the broader population.

Table 2.1- Effect of being an opposite-sex twin (OST) on earnings, compared to same-sex twins (SST) and opposite-sex closely spaced singletons (OS CSS)

Work	Gielen *et al*. (2016) (panels A and B, Model 3)	Huang *et al*. (2019) (Tables 3 and 4)	Peter *et al*. (2018) (Table 4)	Rodrigues (2025) (Table 1.8)
Sample description	165,584 individuals born 1959-1979 and who were employed by firms in 2009.	1,070 individuals, both twins and closely spaced singletons aged 25-32 years.	28,169 dizygotic twins born between 1926 and 1958, with permanent income measured from 1971 to 2007	About 8.5 million individuals, including more than 100 thousand twins, working in the formal labor market in December of 2019 to 2022
Sample contains CSS?	Yes (closed-spaced singletons who have exactly one sibling born within 12 months of their birth date).	Yes (Closely spaced singletons are those with a sibling born within 12 months).	Yes (Closely spaced singletons are those with a sibling born within 24 months)	Yes, but they are not separated from other singletons
Country of the sample	Netherlands	USA (Add Health database)	Sweden	Brazil
OST males earnings, comparing to…				
... the rest of male workers	—	—	—	0.5% to 0.9% **less** than
…SST males	the same as (1)	the same as	1.19% **less** than	the same as
OS CSS males	the same as	—	—	—
OST females earnings, comparing to…				
... the rest of female workers	—	—	—	the same as
…SST females	the same as	11.8% **less** than	the same as	the same as
... than OS CSS females	the same as	—	—	—
Result attributed to	No: "the results do not support the hypothesis that EPT advantages women in the labor market".	Yes (the effect observed in female twins was not observed in CSS).	No (results were similar to those of a CSS sample).	Result attributed to

Source: Own author's elaboration. Notes: (1) Contrary to Huang *et al*. (2019) understanding, I believe that Gielen *et al*. (2016) work showed no statistical differences between OST and SST males. (2) Only coefficients significantly different from zero were described. When available, regressions that had the log of hourly earnings as dependent variable were preferred (as opposed to the log of total earnings).

2.5. DIFFERENCES BETWEEN GENDER THAT MAY AFFECT GENDER GAP

Differences in abilities between genders are a thorny topic in literature. In this work, I do not intend to discover the causes of the difference in abilities nor to affirm that they are innate or acquired. This section only intends to list differences already measured in previous works that may be the source of part of the gender gap.

Since 2000, the OECD’s Programme for International Student Assessment (PISA) has assessed the academic performance of 15-year-old students in more than 70 countries and economies. Across participating regions, girls consistently outperform boys in reading, while boys tend to score slightly higher in mathematics. In science, the gender difference remains negligible — for instance, in 2018, girls scored just two points above boys (OECD, 2020). In Brazil, this same pattern has persisted over time, including in the 2018 cycle (OECD, 2019).

Bharadwaj *et al*. (2016) use detailed Chilean administrative data from 2002 to 2005 to analyse the “math gap” between girls and boys in fourth and eighth grade. The authors use many approaches, including a big sample of opposite-sex twins, and show that the math gap persists, even controlling by the roles played by parents, classroom environments including teacher’s gender and class composition, and individual characteristics of the students[25].

In addition to formal school knowledge, the ability to deal with people and other social behaviors can influence salary. These abilities and behaviors can be measured in different ways. In terms of ”empathy”, for example, Toccaceli *et al*. (2018) used a sample of 1,242 pairs of Italian twins to analyze empathy-related expression in adulthood. The results “confirmed gender differences in adults’ empathy levels”. Females scored significantly higher on the overall scale as well as on the cognitive and emotional subdimensions, but not on the social skills subscale. These differences were shown to be stable across the adult lifespan.

In terms of behavior, men have been consistently shown to drink more alcohol and have a higher likelihood of alcohol use disorders than women in all the world (but due to recent social changes, these differences are narrowing) (Keyes *et al*.,2008). In Brazil, men are more likely to

[25] Please note that the reading and math gaps are only measured for children who go to school. In Brazil, literary rate is slightly higher for Brazilian working age woman than for man, and men tend to drop out school before the end of high school more often than woman (IBGE,2020, and IBGE,2022).

be fired for a just cause[26].

Flinn *et al*. (2018) contribute to the extensive literature highlighting the negative impacts of marriage on women's earnings. By analyzing a panel of approximately 1,800 couples, they found that spouse's personality traits are important determinants of household bargaining weights and of wage offers and have therefore substantial implications for understanding the sources of gender wage disparities. In particular, conscientiousness significantly increases male wage offers and agreeableness — higher in women — significantly lowers wage offers. In total, the authors conclude, "personality traits explain 15.25 percentage points of the offered log wage gap. Their combined contribution to ex- plaining the gender gap is the same magnitude as the contribution of education and working experience".

These outlined above differences, while difficult to measure, may persist even in pairs of OST and may help to explain the "unexplained" gender gap.

2.6. GENDER PAY GAP STUDIES IN BRAZIL

Garcia *et al*. (2009) made a summary of studies about gender gap studies in Brazil conducted up to 2006, and Morello and Anjolim (2021) continued it until 2017. The two compilations together show that a large number of articles point to a gender pay gap between 13% and 33% in Brazil, with some indication of a falling gender gap in recent years. Unfortunately, the studies that focus on total earnings are not totally comparable with those that focus on hourly earnings - the gender gap calculated with hourly earnings tends to be smaller because women on average work fewer hours. Table 2.2 summarizes some studies that analyze hourly earnings and point to an unexplained gender gap (UGP) between 9.2% and 63%. Most studies found that this unexplained gender pay gap fell in the last decades.

Table 2.2- Works on gender pay gap in Brazil that focus on hourly earnings instead of total earnings

	Estimated unexplained gender pay gap	**Reference period**	**Sample**	**Type of job considered**	**Methodology**
Martins (2015)	From 15.7% (in 2003) to 9.2% (in 2013) of the average female salary (=14.6%-8.8% of male salary)	2003, 2008 and 2013	PNAD	Formal and informal	BO

[26] Between 2019 and 2021, men represented about 56% of the stock of formal workers, but they represented 69% of those fired for a just cause MTE (2023).

Madalozzo and Artes (2017)	21.1%	2013	PNAD	Formal and informal	Mincerian regression with gender dummy
Morello and Anjolim (2021)	From 20% (in 1996) to 13% (in 2015) of the average female salary	1996-2015	PNAD	Formal and informal	Ñopo (2008) matching
Urquidi *et al.* (2023)	BO: From 63% (in 1995) to 32% (in 2021) of the average female salary (1); Ñopo: From 44% (in 1995) to 30% (in 2021) of the average female salary.	1995-2021	PNAD	Formal and informal	BO and Ñopo (2008) matching
Fogel and Modenesi (2024)	BO: 25% of the average female salary; Ñopo (adapted): 18.5% of the average female salary.	2009-2018	RAIS from the Rio de Janeiro metropolitan area	Formal	BO and Ñopo (2008) matching (adapted)

Source: author's elaboration. Notes: calculated according to Equation (2.8). Please note that the salaries are in logarithmic form, so the correct interpretation would be "x% of the average female salary in log".

3. METHODOLOGY

3.1. ESTIMATION OF THE UNEXPLAINED GENDER GAP USING BO METHODOLOGY

The first approach used in this paper to estimate the gender pay gap is the traditional BO methodology applied to gender pay gap (developed by Blinder,1973) and Oaxaca,1973) and described by Weichselbaumer and Winter- Ebmer,2005). The first step of this methodology involves estimating two Myncer-type equations separately (one for each gender). For cleanliness, I removed the subscript "i" to denote each of the individuals and use bold to denote the matrix form:

$$\ln(w^M) = \beta_0^M + \beta_1^M \cdot x_1^M + \beta_2^M \cdot x_2^M + \cdots + \beta_k^M \cdot x_k^M + \mu^M \rightarrow \mathbf{ln}(\boldsymbol{w^M}) = \boldsymbol{\beta^M X^M} + \boldsymbol{\mu^M} \quad (2.5)$$

and

$$\ln(w^F) = \beta_0^F + \beta_1^F \cdot x_1^F + \beta_2^F \cdot x_2^F + \cdots + \beta_k^F \cdot x_k^F + \mu^F \rightarrow \mathbf{ln}(\boldsymbol{w^F}) = \boldsymbol{\beta^F X^F} + \boldsymbol{\mu^F} \quad (2.6)$$

where $log(w^{M/F})$ is the logarithm of current earnings per hour of the female (F) and male (M) in formal jobs, in December 2019, 2020, 2021 or 2022. x_1 is a theoretical, non-observable variable that measures the "family quality", i.e., it is a variable that varies by family but not by person in the family. This variable could include items as distinct as "shared genetics", "having a full-time working mother", "absence of father"' and "nutrition received as a child"[27]. x_2 to x_k are the observable variables that vary depending on the person, including age, level of education, occupation, industry, working hours, tenure in the job, etc. μ_i represents other unobservable variables that affect earnings (ability and availability to work overtime when necessary, for example).

After estimating the coefficient from Equations (2.5) and (2.6), it is possible to decompose the wage differential between men and women into an explained part (E) and an unexplained part (U) (Weichselbaumer and Winter-Ebmer,2005).

$$\underbrace{\overline{\ln(w^M)} - \overline{\ln(w^F)}}_{\substack{Gender\ gap \\ measured\ by \\ \ln(OGG+1)(Eq.3)}} = \ln\left[\frac{\overline{\ln(w^M)}}{\overline{\ln(w^F)}}\right] = \underbrace{\left(\overline{\boldsymbol{X^M}} - \overline{\boldsymbol{X^F}}\right)\widehat{\boldsymbol{\beta}^M}}_{\substack{Endowment \\ Effect\ E}} + \underbrace{\left(\widehat{\boldsymbol{\beta}^M} - \widehat{\boldsymbol{\beta}^F}\right)\overline{\boldsymbol{X^F}}}_{\substack{Unexplained \\ Residual\ U}} \equiv E + U \qquad (2.7)$$

In Equation (2.7), the endowment effect E represents the different productive characteristics of men and women. U, in turn, is often referred to as the "discrimination effect" and represents the differences in the estimated coefficients between the two groups (Weichselbaumer and Winter-Ebmer,2005).

The unexplained residual U is commonly expressed as a percentage of woman's average earnings, as seen in Urquidi *et al.* (2023):

$$U\% = \frac{U}{\overline{\ln(w^F)}} = \frac{\left(\widehat{\boldsymbol{\beta}^M} - \widehat{\boldsymbol{\beta}^F}\right)\overline{\boldsymbol{X^F}}}{\overline{\ln(w^F)}} \qquad (2.8)$$

While widely used, the percentage in Equation (2.8) should be interpreted with caution. Firstly, because U is in logarithmic terms, not in actual wage units. Therefore, U% does not

[27] The Brazilian government keeps a record of the weight of the population served free of charge by the Unified Health System (SUS) (Ministério da Saúde,2007). The number of people weighed has increased over time, so the representativeness of the sample has improved. Even so, the data available between 2002 and 2007 — when part of the reference sample for this study was still children — are instructive. 594,000 children between the ages of 0 and 5 were weighed during this period. The percentage of underweight children fell from 35% to 17% between 2002 and 2007. This percentage does not represent the population, since malnourished children are much more likely to be taken for weighing than other children. In any case, in all years, the percentage of underweight boys were slightly higher than the percentage of girls, which contradicts any hypothesis of dietary favoritism of boys (as seen by Khan *et al.*,2015, in India). This allowed me to consider that nutrition received at home in Brazil is roughly the same for boys and girls in the same family.

directly translate to a percentage of the wage in monetary terms (e.g., in Brazilian reais). Instead, it reflects the proportion of the log-transformed female wage that is unexplained by the model. To interpret this in the context of actual wages, one would need to re-estimate Equations (2.5) and (2.6) using the wage in monetary units, not in logarithmic transformation. This complicates a direct percentage interpretation. Thus, one cannot say that, "given D being the difference between male and female wages, U% represents the percentage of D that is not explained by the coefficients". This would be wrong, because U% should not be misconstrued as a straightforward percentage of the actual wage. It is a relative measure based on the logarithmic transformation of wages.

Secondly, U% explains the average wage gap. If the sample distribution deviates significantly from normality, the interpretation of U% can be different or even compromised. Non-normal distributions can affect the reliability of the decomposition results, as the assumptions underlying the Blinder-Oaxaca methodology may not hold. This can lead to misleading conclusions about the unexplained portion of the wage gap.

3.2. ESTIMATION OF THE UNEXPLAINED GENDER USING AN ECONOMETRIC COMPARISON OF PAIRS

BO methodology compares the **averages** of male and female salaries. However, this aggregate approach may obscure individual-level variations. This section focuses on analyzing wage disparities **within matched pairs**, aiming to uncover intra-pair differences that are not evident in average-based analyses.

This section analyzes wages using two distinct types of pairings. The first group consists of OSTs. The second group, termed "random pairs", includes pairs randomly assembled from a large pool of males matched with females born on the same day and within the same region[28]. One could think of the random pairs as "false twins", because both OST pairs and random pairs ensure that individuals being compared share identical ages and regions of birth, providing some common support. This is crucial as age and region are important variables in gender gap studies. The random pairs were randomized twice (generating "Sample 1" and "Sample 2") to

[28] The region of birth was inferred by the number of the person's CPF - most people generate their CPF in their region of birth. I thank my colleague Raoni Ribeiro Aredes de Oliveira for his significant help with the code necessary to form the random pairs.

ensure robust results.

The hypothesis is that shared genetics and a shared environment in early years could lead to a smaller gender gap in OST group compared to random pairs groups. Taking again Equations (2.5) and (2.6) for each individual "i" of the pair "z":

$$\ln(w_i^M) - \ln(w_i^F) = \beta_0^M - \beta_0^F + [\beta_1^M \cdot x_1^M - \beta_1^F \cdot x_1^F] + \cdots + [\beta_k^M \cdot x_k^M - \beta_k^F \cdot x_k^F] + (\mu^M - \mu^F) = \boldsymbol{\beta^M X^M - \beta^F X^F + \mu^M - \mu^F} \quad (2.9)$$

Please note that x_1 does not vary within the same family, so for each pair of twins we have $x_i^M = x_i^F$. Therefore, Equation (2.9) becomes:

$$\ln(w_i^M) - \ln(w_i^F) = \beta_0^M - \beta_0^F + \underbrace{x_1^M[\beta_1^M - \beta_1^F]}_{\substack{for\ twins\ or \\ siblings}} + \cdots + [\beta_k^M \cdot x_k^M - \beta_k^F \cdot x_k^F] + (\mu^M - \mu^F) \quad (2.10)$$

Here, one cannot assume that $\beta_1^M = \beta_1^F$ (as is assumed in Twin Studies with monozygotic pairs), because the same family environment could — in theory — affect man and woman differently (as assumed by Huang *et al.*,2019). There are two situations, however, in which $\beta_1^M - \beta_1^F$ could be zero or very close to zero.

The first situation in which $\beta_1^M - \beta_1^F$ is close to zero is the case where both β_1^M and β_1^F are very close to zero.

This scenario implies that "family quality" exerts a minimal influence on future earnings. Although this assumption seems unlikely, if it were the case, then the estimation using the BO methodology, using Equations (2.5) and (2.6), would yield similar conclusions to Equation (2.10). In such a case, the omitted variable bias inherent in the BO approach would have little effect on the estimation results, given the insignificance of the omitted variable.

The second situation in which $\beta_1^M - \beta_1^F$ is close to zero is the case where where $\beta_1^M \cong \beta_1^F$ that is, the family fixed effects are nearly identical for male and female siblings residing in the same household. While this is unlikely in highly patriarchal societies such as Afghanistan, it may hold true in certain Brazilian families. This implies that aspects of the family environment — such as having a dedicated mother or experiencing poverty — affect both sons and daughters similarly, providing comparable advantages or disadvantages irrespective of gender. This assumption could be problematic for older cohorts — in the decade of 50, for example, very sexist families were more common, and this could have a different impact on career decisions and the possibility of studying for daughters and sons. However, I understand that very unequal treatment between sons and daughters within the same household has become (fortunately) rarer in my reference period (people born between 1996 and 2001). One could also argue that the treatment given to sons and daughters is still unequal in relation to domestic work, and it really is. The IBGE (Brazilian Institute of Geography and Statistics) surveyed the rate at which people aged 16 to 24 performed domestic activities. In 2016, 63% of young men and 85.6% of young women performed some type of domestic activity. However, the difference between the sexes has narrowed considerably, and in 2022, 71.3% of young men and 87.4% of young women performed domestic work (IBGE,2022). In any case, it can be concluded that in every year of the survey, more than half of households requested domestic work from both sexes, and, even with a greater domestic workload, women consistently outperform men in school - suggesting that this extra burden does not impact academic outcomes. Variables such as family income and mother's education, which are factors shared between twins, are much more important in explaining future income than the number of hours spent on domestic activities. Therefore, I believe the hypotheses of similar family environmental coefficients for men and women holds.

If the hypothesis that $\beta_1^M - \beta_1^F$ is close to zero is true (due to case 1 and/or 2), then the element $x_1^M[\beta_1^M - \beta_1^F]$ is close to zero and it could be estimate — for the OST group — a non-biased version of Equation (2.10) ignoring variable x_1:

$$\ln(w_i^M) - \ln(w_i^F) = \beta_0^M - \beta_0^F + [\beta_2^M \cdot x_2^M - \beta_2^F \cdot x_2^F] + \cdots + [\beta_k^M \cdot x_k^M - \beta_k^F \cdot x_k^F] + (\mu^M - \mu^F) \quad (2.11)$$

3.3. ESTIMATION OF THE UNEXPLAINED GENDER GAP USING ÑOPO APPROACH (COMPARING OPPOSITE-SEX TWINS AND RANDOM PAIRS)

This section compares the same opposite-sex twin (OST) and random male-female pairs described previously, using a non-parametric matching strategy inspired by Ñopo (2008). Ñopo's method estimates the unexplained gender pay gap by comparing each woman to a "synthetic man" — a male counterpart with identical observable characteristics, selected from the region of common support where both groups share comparable profiles. The idea is to isolate the portion of the wage gap that cannot be explained by differences in observable attributes.

In this study, I adapt Ñopo's approach by comparing each woman to a single man with common support. For OSTs, this man is her twin brother — someone who shares not only observable characteristics but also unobservable ones like family background and early-life environment. As Ñopo himself noted in personal correspondence, twins are "naturally matched" (Ñopo, 2024), making them ideal for this type of analysis. This design allows for a cleaner estimation of the unexplained gender gap by minimizing both observable and unobservable differences between individuals.

The focus of the analysis is on the unexplained part of the gender gap, expressed by Ñopo (2008) as the Δ_0, the difference between the average wage differences of the matched pairs, or the average hourly wage difference of the pairs:

$$\Delta_0 = \frac{1}{N}\sum_{i=1}^{N}\left[w_{i,match}^{M} - w_{i,match}^{F}\right] = \frac{1}{N}\sum_{i=1}^{N}\left[\Delta w_{i,match}\right] = \overline{\Delta w_{i,match}} \tag{2.12}$$

Ñopo's (2008) approach analyzes the unexplained gender wage gap in monetary units, rather than as a percentage of female wages, as done in Equation (2.8). The average hourly difference $\overline{\Delta w}$ - used in Equations (2.2) and (2.3)- becomes Ñopo's unexplained gender gap only when we compare matched pairs: $\overline{\Delta w_{i,match}}$.

This section's pairing methodology offers both strengths and limitations. A key advantage lies in its clear framework for comparing individuals with shared characteristics, aligning with the non-parametric matching strategy proposed by Ñopo (2008). In particular, the methodology facilitates more meaningful comparisons by reducing heterogeneity between matched individuals. However, it remains sensitive to outliers, which may distort the estimated gender gap.

To address this, I report both the average and median unexplained gender gap based on Equation (2.12).

While Ñopo's (2008) methodology does not explicitly predict outcomes for specific groups such as opposite-sex twins (OST) or random pairs, its underlying principles suggest that comparing individuals with more similar observable characteristics can lead to a smaller unexplained gender wage gap. In the context of this study, OST pairs are likely to share more similar observable and unobservable characteristics than randomly matched pairs. Therefore, applying Ñopo's matching approach may result in a smaller unexplained wage gap for OST pairs, as the method emphasizes comparisons within common support to minimize differences attributable to unobserved factors. Conversely, random pairs, despite being matched on certain criteria like age and region of birth, may exhibit greater variability in unobserved characteristics, potentially leading to a larger unexplained gap.

By controlling more precisely for observed characteristics in the OST group, this approach isolates the residual gender gap more effectively. As a result, it provides a cleaner estimate of the role played by unobserved factors and potential gender discrimination.

4. DATA

In this work, I use a database of Brazilian twins, the "TwinsBR" database, built and described in great detail in Rodrigues (2025). TwinsBR is a large database that contains information about twins, including 95,580 pairs of opposite-sex twins (OST). These individuals were born between 1986 and 2001 and appear in the formal labor market records for at least one of the reference months: December 2019, December 2020, December 2021 and December 2022. As explained in Rodrigues (2025), information from the individuals came from the CPF's database (RFB, 2023) and information on wages came from MTE (2023). All data was read and manipulated using R Core Team (2022).

Following the criteria established by Rodrigues (2025) — specifically, selecting individuals whose mothers have unique names, enabling the mother's CPF identification — the sample was expanded to include all singletons born in the same period whose mothers also met this condition. This approach yielded a dataset comprising over 8 million individuals observed across multiple reference months. The identification of the mother facilitated the extraction of detailed family-level information, such as the number of siblings, birth order, and the gender composition of the household. Additionally, it allowed for the determination of whether an individual had recently lost their mother.

To ensure data quality and consistency in analyzing gender disparities, the sample was confined to individuals born between 1986 and 2001, aged 18 to 36 during the 2019–2022 observation period. This age range was chosen to mitigate issues related to missing maternal information, which are more prevalent among older individuals and can complicate sibling identification and twin classification. Moreover, as highlighted by Bingley et al. (2009), gender wage gaps exhibit age-dependent variations. By narrowing the age range, the analysis reduces the risk of confounding effects related to age and time.

5. RESULTS

5.1. RAW GENDER GAP

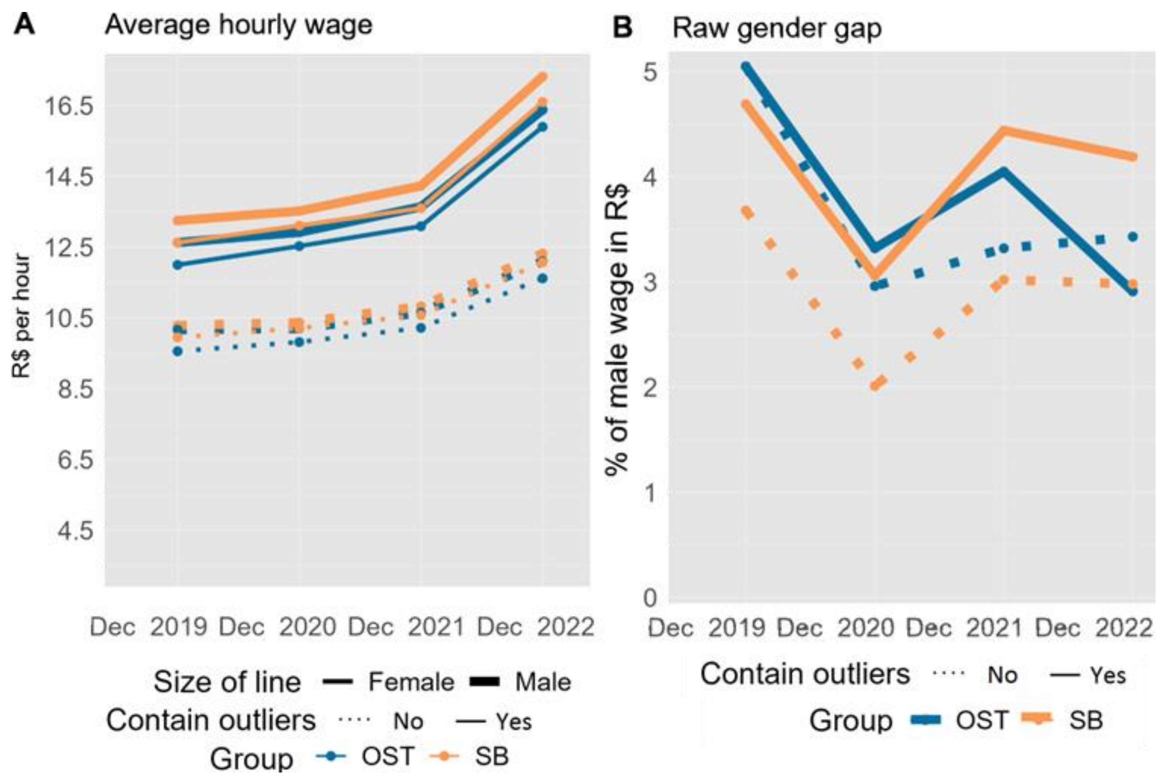
As of December 2022, women employed in formal jobs in Brazil earned an average monthly salary of R$ 3,481.57 (approximately US$ 667.34). In contrast, men in formal employment positions earned, on average, 12.42% more (MTE, 2024a). Since women worked on average fewer hours, the hourly raw gender gap was smaller (around 7.3%)[29]. In the age range used for this study (born between 1986 and 2001, therefore between 21 and 36 years in 2022), the hourly raw gender gap is smaller - 4.19% according to my calculations[30]. This is consistent with the fact that the gender gap is smaller in younger cohorts. The relatively small raw gender gap is also consistent with the fact that women have a higher average education level, thereby contributing to narrowing the raw gender gap (but not the unexplained gender gap).

The hourly wages and raw gender gap for the sample used in this study are depicted in Figure 2.1.

Figure 2.1 – Average hourly wages in R$ and raw gender gap in % of Opposite-sex twins (OST) and Single childbirth (SB) groups

[29] According to the official report on gender wage differences (MTE, 2024b), women earned on average R$ 3,904 in December 2022 and the raw gender gap was 19.4%. However, this report is based solely on big companies. Here, I used the full dataset on formal jobs available at MTE (2025) and the summary available at MTE (2024a).

[30] All calculations performed using micro data considered only the primary job of each individual. The sample was restricted to individuals who worked more than two hours per week, as the few observations with less than three weekly hours appeared to have issues with accurate reporting. Additionally, observations with likely verifiable reporting errors, such as those with an hourly wage below the minimum wage or above 150 times the minimum wage, were excluded.



Source: database built by the author from MTE (2023) and RFB (2023). Notes: The left chart had its axis cut in R$ 4 because the hourly minimum wage in 2019 was above this value, so the average hourly wage could not possibly be smaller than that.

5.2. ESTIMATION OF THE UNEXPLAINED GENDER GAP USING BO METHODOLOGY

Four traditional Blinder-Oaxaca (BO) estimations were conducted — one for each year — applying Equations (2.5) and (2.6)[31]. After excluding outliers, each annual sample comprised approximately 9 million individuals born between 1986 and 2001, all engaged in formal employment. Among these, over 32,000 were identified as opposite-sex twins (OSTs). The substantial sample size facilitated the inclusion of standard covariates such as age, tenure, sector, occupation, and industry, along with additional variables related to birth circumstances (e.g., mother's age at childbirth, OST status) and current conditions (e.g., a binary indicator for maternal death within the year). Detailed results for December 2022 are presented in Appendix C, with similar patterns observed in the preceding years.

Two issues from these estimations are important for this work. First, wages of OST males do seem to be slightly smaller than those of singleton males - the same conclusion of Rodrigues (2025). Second, this small difference reflects in a slightly smaller gender gap, but

[31] As the family environment is not observed, the variable x_1 was excluded from every BO estimation in this work.

the difference is not statistically significant. In other terms, one cannot conclude that the gender gap of OST group is smaller than those of the singleton group.

However, due to possible heterogeneity of the singletons and OST groups, I also performed BO estimations separately for each group, using both the log of wage and the wage in monetary units as dependent variables. Table 2.3 shows the unexplained gender gap (UGP) calculated by each of these estimations. The result differs greatly in size depending on the dependent variable chosen, but the conclusion is the same: the UGP is statistically the same for both groups[32].

The estimates of the unexplained gender pay gap (UGP) reported here are smaller than those presented by Fogel and Modenesi (2024) (see Section 2.6). Part of this difference may reflect the gradual narrowing of the gender gap over time. However, the primary reason likely stems from differences in sample composition: the TwinsBR dataset focuses on a younger cohort, which limits direct comparability.

Table 2.3 - Unexplained gender gap according to estimated BO methodology

Dep. variable	Sample with outliers?	Group	Dec 2019	Dec 2020	Dec 2021	Dec 2022
Number of individuals		Singletons	8,293,265	8,466,876	9,607,383	9,439,408
		Opposite-sex twins	32,664	37,024	36,060	37,406
Log of hourly wage *ln*(*w*)	Yes	Singletons	6.19	6.17	6.08	6.04
	Yes	Opposite-sex twins	6.05	6.07	5.95	5.79
	No	Singletons	5.36	5.39	5.25	5.25
	No	Opposite-sex twins	5.36	5.36	5.32	5.26
Hourly wage in R$ R$ w	Yes	Singletons	23.31	23.77	23.90	24.87
	Yes	Opposite-sex twins	21.34	22.25	22.58	20.43
	No	Singletons	10.96	11.02	10.81	11.30
	No	Opposite-sex twins	12.05	12.12	11.99	12.49

Source: author. The UGP is calculated according to Equation (2.8) when the dependent variable is the log of hourly wage. When the dependent variable is the hourly wage, the UGP is calculated as $UGP = \frac{\left(\widehat{\beta^M} - \widehat{\beta^F}\right)\overline{X^F}}{\overline{w^F}}$. See Section 3.1 for more details on the differences between these two measures.

The conclusions outlined above should be seen with caution, not only because the residuals are far from normal but also because one should not interpret that the gender gap within the pair of OST is the same as those seen in any average pair. BO equations compare

32 A z test was conducted to determine whether the unexplained gender gap, measured as in Equation (2.7): $U = \left(\widehat{\beta^M} - \widehat{\beta^F}\right)\overline{X^F}$, was "bigger", "smaller" than, or "the same" as the singleton's UGP. In all the tests conducted, UGP was statistically the same for both groups.

average salaries — in that case, it tells us (again) that the OST group does not differ substantially from the group of singletons. It tells nothing about the gender gap within each pair.

5.3. ESTIMATION OF THE UNEXPLAINED GENDER GAP USING AN ECONOMETRIC COMPARISON OF PAIRS

An econometric analysis was conducted to investigate gender wage disparities by comparing pairs with common support: opposite-sex twins (OSTs) and random pairs matched by birth date and region. The regression model, based on Equation (2.9), utilized wage differences (in monetary units) as the dependent variable and incorporated a comprehensive set of covariates.

Notably, this econometric analysis contributes to the literature not only through its unique pairing methodology but also by integrating family-related variables seldom explored in Brazilian wage analyses. These include indicators such as maternal death in the reference year, birth order, and family composition. By encompassing these factors, the model offers a more nuanced understanding of the determinants influencing gender wage gaps.

The regression results, detailed in Table 2.4, reveal that traditional covariates behave as anticipated: if the male in the pair has more education, tenure, or works in a wealthier city, the gender gap will be larger (i.e., all else being equal, the male will earn more). Similarly, if the male has a disability or lost his mother in current year, the gender gap will be smaller.

For the purposes of this work, three key dummy variables were included: (1) "male has a sister," indicating whether the male in the pair has at least one sister; (2) "female has a brother," indicating whether the female has at least one brother; and (3) "is random pair," identifying whether the pair is a randomly matched male-female pair rather than an OST. Notably, all OSTs inherently satisfy the conditions of the first two variables, as they consist of a male and a female twin. Therefore, the control group for the “is random pair” dummy comprises opposite-sex twins (OSTs), while the treatment group includes random pairs where the male has at least one sister and the female has at least one brother[33].

[33] According to my calculations, based on the human natural ratio (105 males to 100 females born) and to the distribution of family size in Brazil in 2010 Census, the probability of a female having at least one brother born alive is 67.7%.

The regression results also reveal that the coefficients for both "male has a sister" and "female has a brother" are positive and statistically significant. This suggests that, on average, pairs where the male has a sister or the female has a brother exhibit a larger gender wage gap compared to pairs where these conditions do not hold. Specifically, the presence of an opposite-sex sibling is associated with higher earnings for men but not for women: holding other factors constant, males with at least one sister tend to earn **more** than males without sisters, while females with at least one brother tend to earn **less** (or the same, depending on the year) than females without brothers.

However, contrary to expectations, the regression results indicate no statistically significant difference in the gender wage gap between opposite-sex twins (OSTs) and random pairs where both the male has at least one sister and the female has at least one brother. Specifically, the coefficient for the "is random pair" dummy variable is negative but not statistically significant, Specifically, it indicates that the gender gap between twins is the same as the gender gap found in random pairs where both have an opposite-sex sibling.

Overall, these findings imply that the presence of opposite-sex siblings is associated with a wider gender wage gap, whereas the method of pairing (OSTs versus random pairs) does not significantly influence the observed wage disparities.

Table 2.4- Econometric Regressions on Salary Differences between male and female individuals born on the same day and region, in BRL (nominal)

	Dec2019	**Dec2020**	**Dec2021**	**Dec2022**
Constant	1.283**	3.654***	2.160***	3.770***
Difference in level of education (1)	1.211***	1.217***	1.247***	1.540***
Difference in tenure, in months (1)	0.028***	0.035***	0.034***	0.028***
Difference in contract hours (1)	−0.313***	−0.320***	−0.307***	−0.358***
Difference in age of the mother at childbirth (1)	0.011***	0.014***	0.016***	0.020***
Difference in number of job exits in the last 3 years (1)	−0.143***	−0.196***	−0.302***	−0.686***
Difference in gdp per capita of male and female's city	0.00002***	0.00001***	0.00001***	0.00001***
(1)				
Difference in number of siblings (1)	−0.112***	−0.112***	−0.114***	−0.134***
Age in years	−0.082***	−0.149***	−0.083***	−0.090***
Age^2 in years	0.004***	0.005***	0.003***	0.004***
Dummy: male has disability	−1.032***	−1.006***	−1.036***	−0.933***
Dummy: female has disability	0.441***	0.481***	0.484***	0.422***
Dummy: male's mother died before he was 11 years	−0.043	−0.162	−0.190*	−0.292**
Dummy: female's mother died before she was 11 years	0.140	0.174	0.102	0.256*
Dummy: male's mother died in current year	−0.528***	−0.416***	−0.402***	−0.393***

Dummy: female's mother died in current year	0.217**	0.211**	0.433***	0.645***
Dummy: male has sister	**0.039*** **	**0.055*** **	**0.057*** **	**0.042** **
Dummy: female has a brother	**0.040*** **	**0.012**	**0.020**	**0.034** **
Dummy: male has closely-spaced brother or sister (2)	0.071***	0.072***	0.037**	0.094***
Dummy: female has closely-spaced brother or sister (2)	−0.065***	−0.084***	−0.072***	−0.108***
Dummy: male is secondborn	0.092***	0.068***	0.072***	0.094***
Dummy: male is thirdborn	−0.010	−0.036	−0.073***	−0.094***
Dummy: male is fourthborn	−0.041	−0.023	−0.020	−0.075*
Dummy: male is fifthborn	0.261***	0.204***	0.146***	0.191***
Dummy: male is sixthborn or later	0.658***	0.619***	0.548***	0.611***
Dummy: female is secondborn	−0.026*	−0.019	−0.014	0.015
Dummy: female is thirdborn	0.101***	0.119***	0.125***	0.178***
Dummy: female is forthborn	0.114***	0.127***	0.166***	0.243***
Dummy: female is fifth born	−0.053	0.035	0.043	0.170**
Dummy: female is sixth born or later	−0.451***	−0.386***	−0.412***	−0.368***
Dummy: type of pair= Random pair	**−0.057**	**−0.074**	**−0.087**	**−0.015**
Race dummies	Yes	Yes	Yes	Yes
Occupational dummies	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Legal nature of employer dummies	Yes	Yes	Yes	Yes
R^2 Robusto	0.2429	0.2458	0.2296	0.1316
F-statistic	7420.9644	8015.4739	9529.9673	8154.832
Pr(F)	0	0	0	0
Observations	1,491,908	1,514,031	1,906,868	1,866,809
Residual Std. Error	6.313 (df = 1491715)	6.582 (df = 1513838)	6.787 (df = 1906675)	8.586 (df = 1866616)

Source: author. Notes: (1) All differences are calculated as (value for the male in the pair) minus (value for the female in the pair). (2) A closely spaced brother or sister is one that is born no more than 24 months before or after the individual analyzed. (3) The more positive the coefficient, the larger the gender gap (i.e., the male in the pair earns more than the female in the pair). (4) *p<0.1; **p<0.05; ***p<0.01 (5) Coefficients for racial, occupational, regional, and legal nature of employer dummy variables are omitted for brevity.

Even considering the estimation issues (non-normality of residuals and a low R^2), the result is somewhat surprising. The conclusion that the gender gap is the same between pairs of opposite-sex twins and random pairs could imply that shared genetics and a shared childhood environment have little impact on earnings. There are several possibilities to consider here.

The first is that parents of opposite-sex twins are exceptionally efficient in raising opposite-sex siblings simultaneously while providing different guidance depending on gender, which would lead to the continuance of gender conformity. I find that the opposite is more probable — when one has opposite-sex twins as siblings, it is more likely that each sibling has more contact with the opposite gender's (visible and invisible) norms. He or she should be able to take more advantage of it than singletons.

The second hypothesis is that the long-standing belief that "specifics of family environment are important to explain the gender gap" is not as significant as previously thought. Perhaps societal norms are more influential, and even when parents raise opposite-sex siblings in a similar manner, gender conformity still occurs. In other words, shared genetics and shared home environment are less important than other factors that explain the gender gap.

The third hypothesis is that having an opposite-sex sibling increases gender disparities (benefits male's wages), so opposite-sex twins might not be an ideal common support. This possibility is confirmed by the slightly positive values for the dummies "male has sister" and "female has brother". I would not be the first to reach this conclusion[34].

5.4. ESTIMATION OF THE UNEXPLAINED GENDER GAP USING N˜OPO METHODOLOGY

In this section, I continue the comparison between opposite-sex twin (OST) pairs and randomly matched male-female pairs. I now apply Ñopo's (2008) matching framework to refine the definition of common support (see Section 3 for a detailed discussion) and to focus specifically on the unexplained component of the gender pay gap. To the best of my knowledge, this is the first time such visualizations appear in the literature, so I dedicate additional space to presenting and interpreting them.

I begin by reporting the gender gap in monetary terms, following the approach proposed by Ñopo (2008) and formalized in Equation (2.12). To enhance comparability with the Blinder-Oaxaca (BO) decomposition results, I also express the gap as a percentage of male earnings, as shown in Equation (2.4).

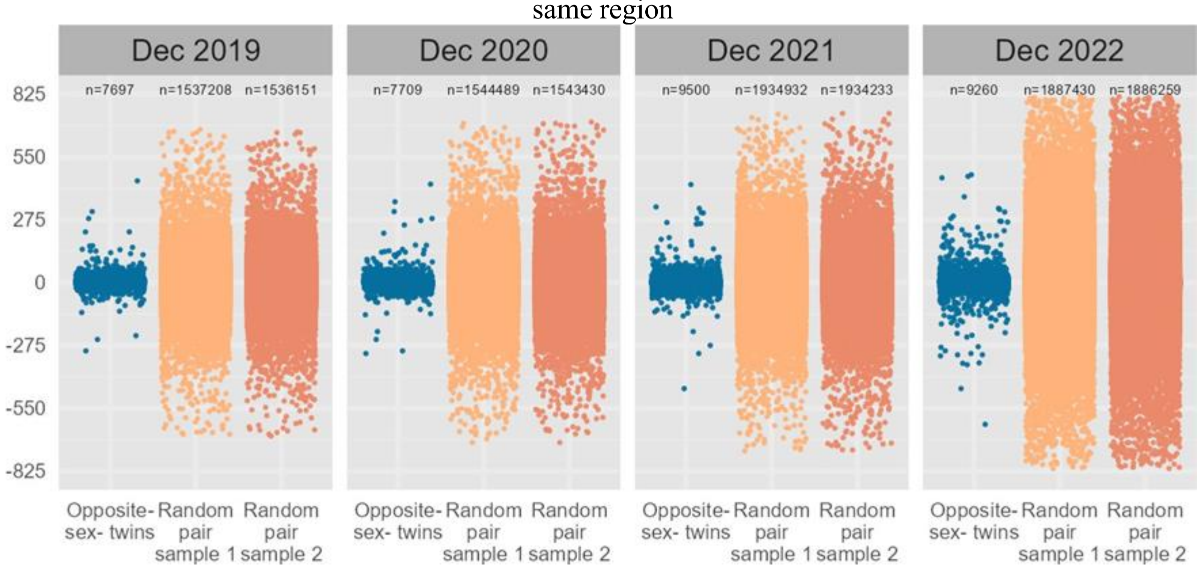
5.4.1. Unexplained gender gap within pairs measured in monetary units

Figure 2.2 presents boxplots of the hourly wage differences (Δw_i, in R$) of men and women in OSTs and random pairs. The dispersion within the pairs is so significant that the boxplots are barely visible, with only the outliers being observable. However, this is consistent with the high level of

[34] An interesting analysis of the negative impact of having a brother on females' wages was conducted by Oguzoglu and Ozbeklik (2016). They investigate the potential role of fathers in females' decisions to choose a STEM major in college—a high-paying career. The authors find that, for females, having brother(s) significantly decreases the likelihood of choosing a STEM major. They believe that fathers are more likely to transmit occupation-specific tastes and preferences to their daughters in the absence of a son.

income inequality observed in Brazil. The variance in the OST group is significantly smaller.

Figure 2.2 – Hourly wage differences (Male – Female) in R$ in pairs born on the same day and in the same region



Source: Author's calculations. Notes: (i) hourly wages smaller than the minimum wage or bigger than 150 times the minimum wage were excluded. (ii) Positive values in the boxplot means that the man earns more than the woman of the pair. (iii) Please note the bigger dispersion and size of the sample of December 2022. This is partly due to methodological changes that increased the quality of data (MTE, 2023).

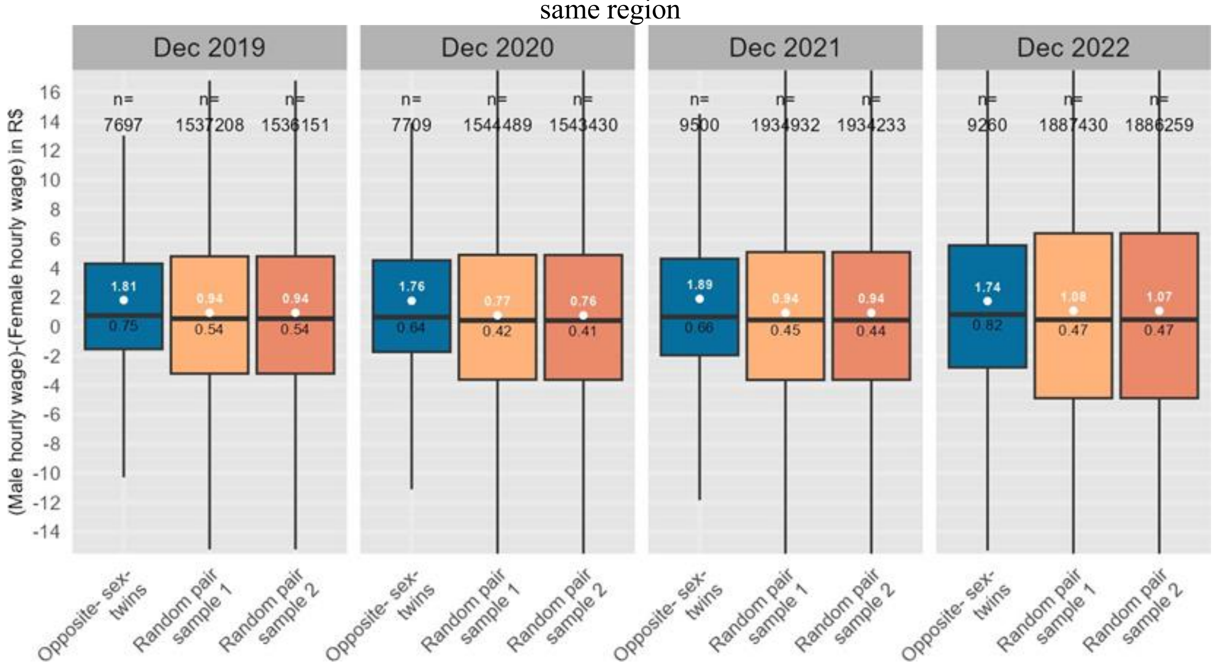
The same boxplot without outliers is shown in Figure 2.3. Even controlling for age and region, gender gap was positive for all the groups and years[35]. In December 2022, for example, OST males earned on average R$ 1.74 per hour more than their co-twins sisters. This means that in a year, OST males would earn R$ 4,099.45 more than their co-twins[36]. This extra earning amounts to 3.4 times the monthly minimum wage in Brazil and more than the monthly average wage. To put it simply: male and female OST work, but males earn the equivalent of a month of work more per year.

What is important for the purposes of this paper is that, in all the years seen in Figure 2.3, the average and the median hourly wage difference (Δw_i) are bigger for the OST group than for the random pairs[37]. This may seem surprising at first glance. However, this may be due to the fact that, in society as a whole, women study more years, thus narrowing the gender gap.

[35] Both the average and the median hourly wage difference (Δw_i) are different from zero, according to the t test and Wilcox text, respectively. In this session, all the tests performed used the confidence level of 10%.
[36] The calculus considers 44 hours worked per week and 12 months of paid work.
[37] The average hourly difference (Δw_i) was compared for the groups "OST", "Random pair Sample 1" and "Random pair Sample 2" using a t test. OST average was considered "bigger" if the t test confirmed it was bigger than the average of the two other groups. The median was compared using a Wilcox text.

However, within twins, the difference in years of schooling is smaller, so this variable “helps less” in the OST group.

Figure 2.3 – Hourly wage differences (Male - Female) in R$ in pairs born on the same day and in the same region

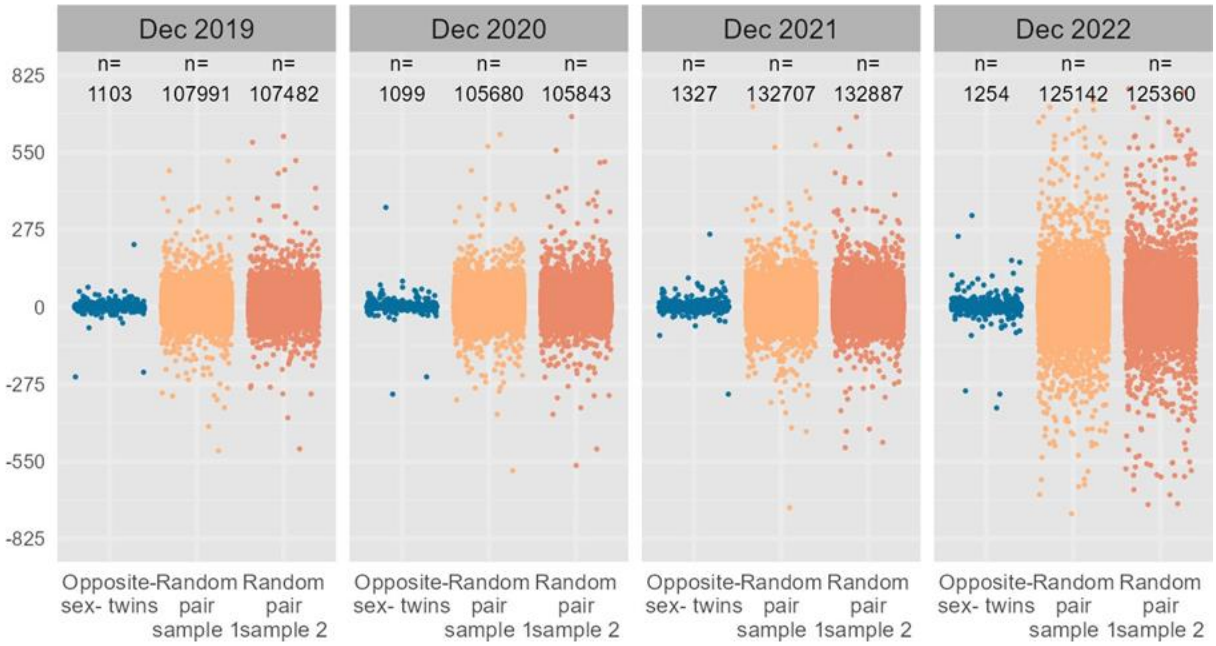


Source: Author’s calculations. Notes: The same as for Figure 2.2.

When the common support is narrowed down in the direction of matched pairs, the conclusion changes slightly. Figure 2.4 shows the differences in wages (Δw_i) in a special subsample of the pairs previously seen, the one with a triple common support: those who not only are born in the same day and region, but also have the same occupation. This subsample is special because it allows individuals to have different strategies to improve their wage in the same occupation. Men may be available to work longer hours (Goldin,2014) and women may study more, for example. Please note that this is still a big sample - more than 1,100 pairs of OSTs are observed each year, a figure that is significant in any Twin Study. Also, note that around 14% of OST pairs have the same occupation, while around 7% of random pairs exhibit the same pattern.

The most visible conclusion here is that for all the groups, including occupation as a common support significantly reduces the variance of Δw_i - a conclusion confirmed by the F test.

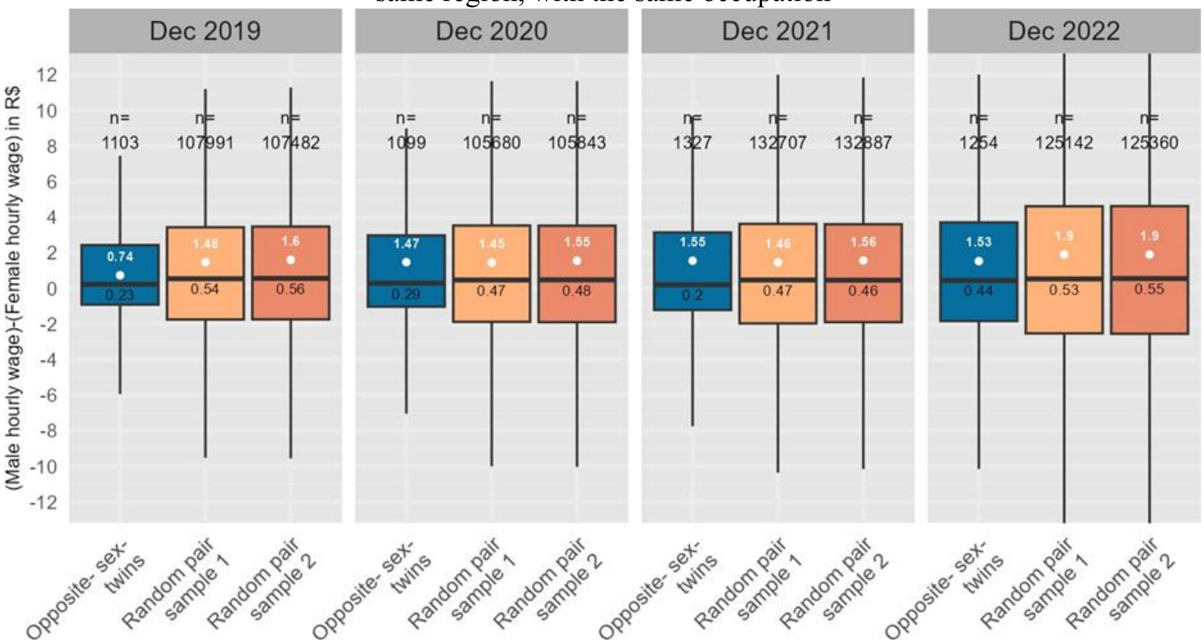
Figure 2.4 – Differences in Hourly Wages (Male – Female) in R$ in pairs born on the same day and in the same region, with the same occupation



Source: Author's calculations. Notes: the same as for Figure 2.2.

Excluding outliers from Figure 2.4, we obtain Figure 2.5. Compared to Figure 2.3, when occupation is added as a common support, the OST's average Δw_i for OST falls and the random pairs increase (i.e, they become more uniform). Here, we cannot reject the hypothesis that the average Δw_i is the same for all the groups in each year, and the same can be said about the median.

Figure 2.5 – Hourly wage differences (Male – Female) in R$ in pairs born on the same day and in the same region, with the same occupation



Source: Author's calculations. Notes: The same as for Figure 2.2.

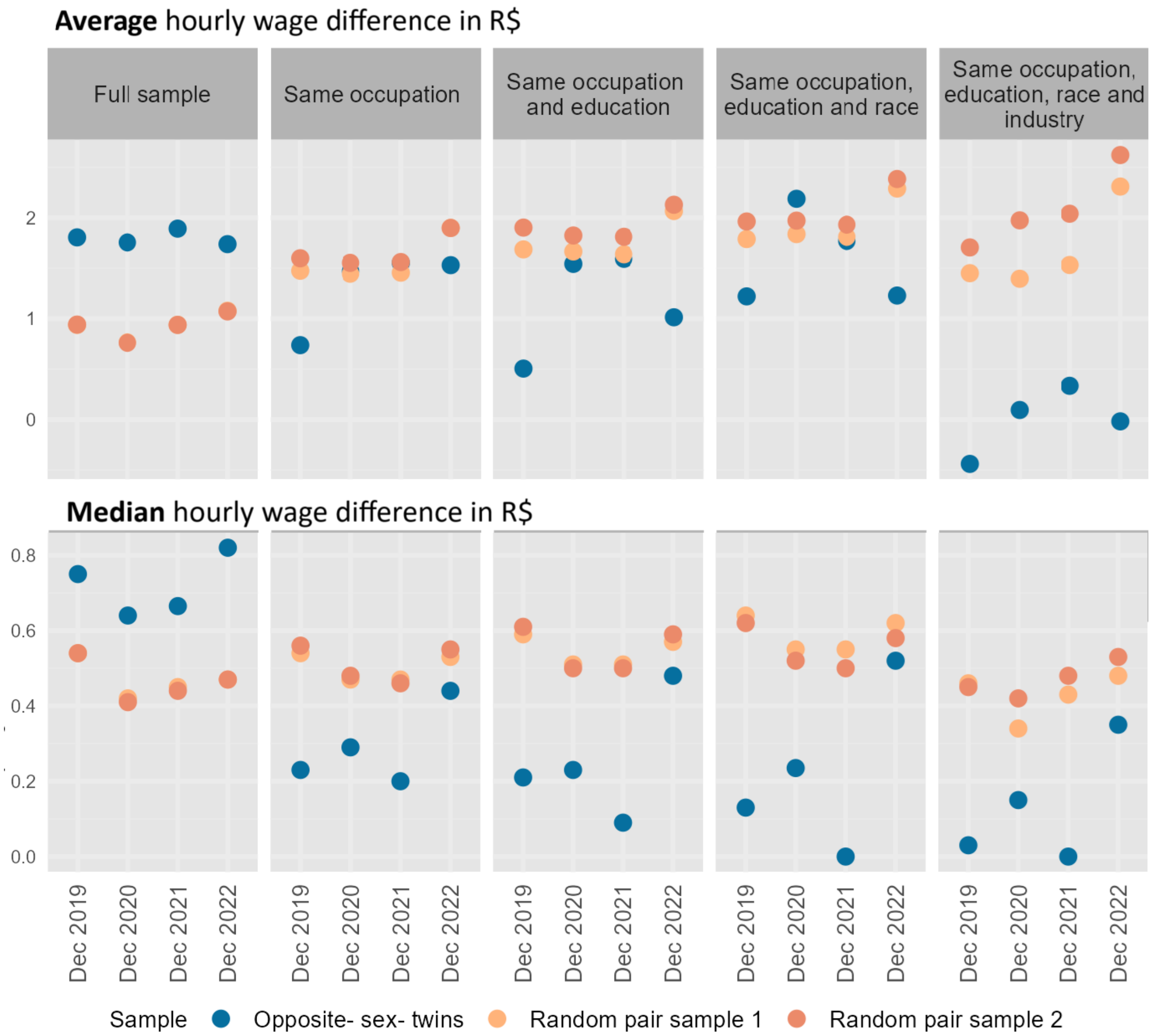
Additional variables, such as level of education, race, and industry, were incrementally incorporated into the common support until the "matched pairs" stage was achieved, allowing for the calculation of the unexplained gender gap as indicated by Ñopo (2008). Figure 2.6 shows the results. The left chart considers all the supports — age, region, occupation, education, race[38] and industry — and therefore measures the unexplained gender gap Δ_0 as calculated by Equation (2.12).

The main conclusions <u>for the average</u> Δw_i $(\overline{\Delta w_i})$, all tested with a t test, are the following: **(a) for the full sample and for the sample with pairs with same occupation**, $\overline{\Delta w_i}$ is solidly positive, meaning that on average the men of the pair earn more than the women; and **(b) the more variables I added to the support , $\overline{\Delta w_i}$ got smaller for the OST group, to the point it was no different from zero** in the left chart, which corresponds to Δ_0 as calculated by Equation (2.12). This means we cannot reject the idea of no unexplained gender gap for this subsample, which included more than 220 pairs observed each year. On the other hand, **$\overline{\Delta w_i}$ remained positive for the random pairs even with all the supports**. This suggests OST are natural matches while random pairs still have unobservable variables that could explain these differences.

The main findings <u>for the median</u> $\Delta w_{i,}, Med[\Delta w_i]$, tested using the Wilcoxon signed-rank test, reveal a slightly different pattern. **As more support variables are added to the matching process, the median gap decreases. However, this happened to all groups in a similar manner.** For the three charts on the bottom left, the test fails to reject the null hypothesis that the medians are equal and different from zero across the three groups — that is, **the median unexplained gender gap remains positive**. Still, the estimated medians are small, around 45 centavos of the Brazilian Real in 2022, which corresponds to approximately 4.5% of the average hourly wage (see Table 2.3).

Figure 2.6 – Average and median Hourly wage differences in R$ in pairs with common support

[38] Race was added as a support because the purpose of this paper is to investigate the unexplained **gender** gap. More studies are necessary to investigate the unexplained racial gap.



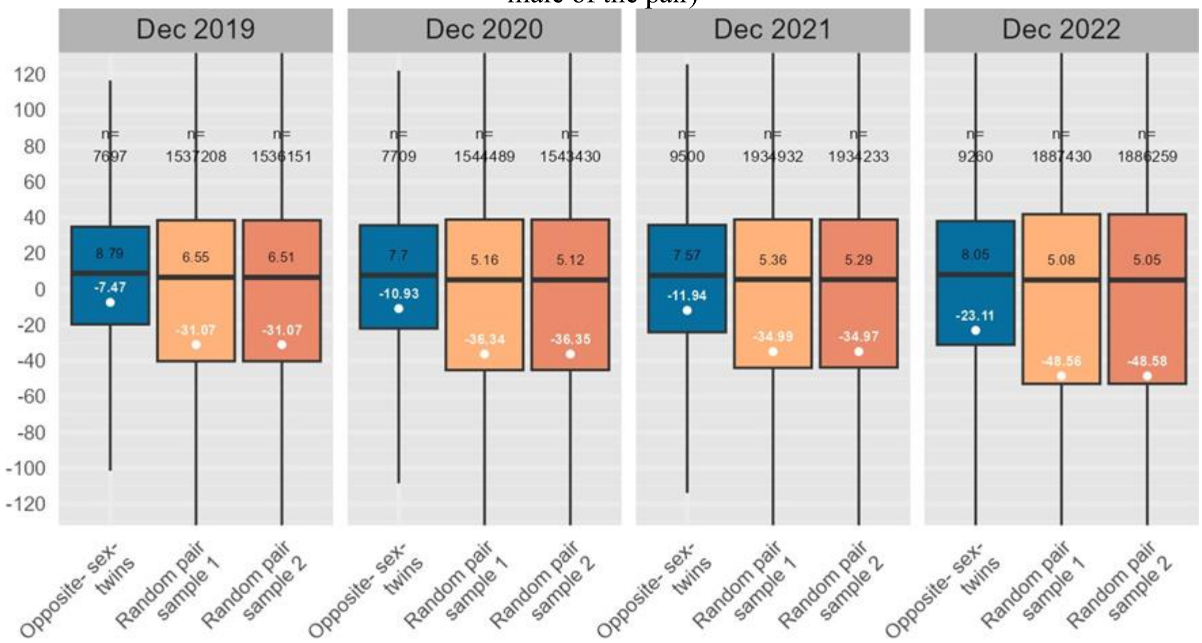
Source: Calculated by the author using Equation (2.4).

5.4.2. Gender gap within pairs measured in percentage of male's wage

Figure 2.7 shows the pair gender gap, as calculated by Equation (2.4), for the same pairs in Figure 2.2, excluding outliers for better visualization. It is equivalent to Figure 2.3 but expressed as a percentage of the wage of the male of each pair. The negative average is surprising, but it does not mean that women earn more on average (see Figure 2.3 to check that this is not the case). Rather, it indicates that there are many cases where women earn slightly more than men. For example, a pair in which the man earns R$9 and the woman earns R$13 (close to the average female salary) would generate a PGG of -30.8%, thus affecting the average PGG more than a case where the men earns R$14 and the woman earns R$13. The gender gap measured on a pair-by-pair basis is very sensitive to low values of male salaries, as discussed in Section 2.1.

What is most important for the purposes of this paper is that the conclusion drawn from Figure 2.3 is very similar to the conclusion here: in the full sample of pairs, the gender gap in OST is larger than in random pairs: not only is the median higher every year, but the average is less negative. All differences were statistically tested using t-tests and Wilcox tests.

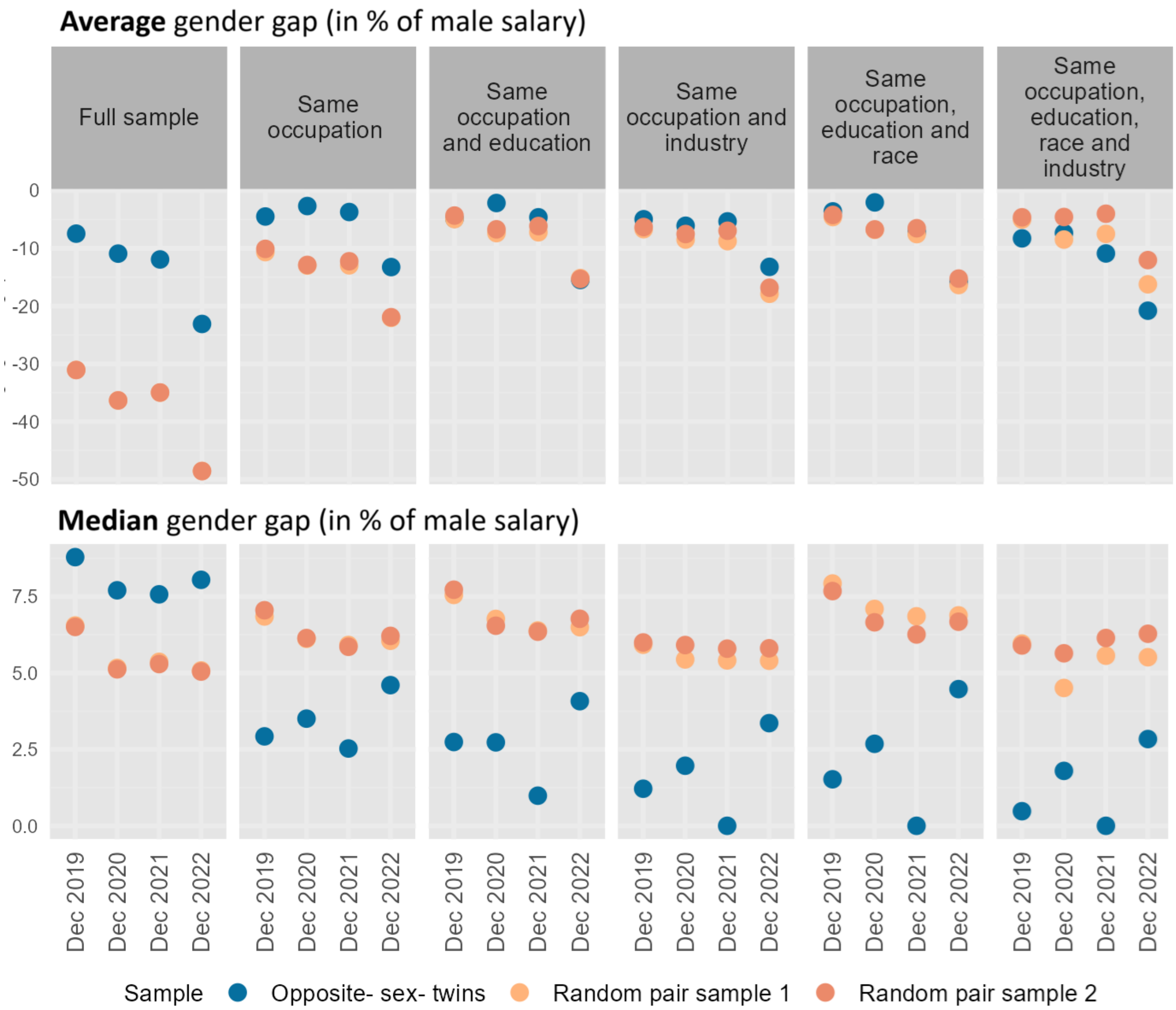
Figure 2.7 – Gender gap in pairs born on the same day and in the same region (in % of the wage of the male of the pair)



Source: Author's calculations using Equation (2.4). Notes: (i) Positive values indicate the percentage by which the man earns more than the woman of the pair (ii) Hourly wages smaller than the minimum wage or bigger than 150 times the minimum wage were excluded. (iii) Outliers were not shown for better visualization.

Figure 2.8 shows the evolution pair gender gap when we add more variables to the support. Here, we see a much more stable pattern than those seen when we analyze the gender gap in monetary units (compare again to Figure 2.3). Here, the average pair gender gap is very similar, no matter how many controls are added. The median pair gender gap, on the other hand, exhibits a similar pattern than those seen in Figure 2.6: the OST group has a much smaller unexplained gender gap.

Figure 2.8 – Average and median gender gap in % in pairs with common support



Source: Calculated by the author using Equation (2.4). The same notes shown in Figure 2.7 apply.

6. CONCLUSIONS

This study offers an initial exploration of the potential for using opposite-sex twins (OST) to analyze the gender pay gap.

The parametric analysis, based on Blinder (1973) and Oaxaca (1973), did not yield valuable insights as it compares group averages rather than the gender gap within pairs. However, it demonstrated that OSTs are a valid group for analysis, as their average wages are similar to those of singletons.

The non-parametric analysis, inspired by Ñopo (2008) and adapted to compare OSTs with randomly matched male-female pairs born on the same day and in the same region, uncovered several novel findings. The discussion that follows focuses on the gender pay gap expressed in monetary terms, as recommended by Ñopo (2008).

First, contrary to my initial hypothesis, opposite-sex twins (OSTs) exhibit a larger gender gap than randomly paired individuals. This pattern appears consistently across all years analyzed, both in terms of average and median gender gaps. This may be because, in random pairs, the average level of education is higher for females than for males, thus narrowing the gender gap in these groups. In the OST group, the level of education is more uniform, so this variable contributes less to reducing the gender gap. Other possibilities, beyond the scope of this work, include the potential influence of having a brother on the gender gap.

Second, the unexplained gender gap — the portion of the gender gap that remains for matching pairs with common support — is smaller for OSTs. In fact, for the sample of young adults analyzed, this unexplained gender gap is statistically indistinguishable from zero in all years. In other words, there is a subgroup of opposite-sex twins that are truly matched pairs: their shared genetics and/or background are similar enough to lead them to similar choices in education level, occupation, and even industry. For this subgroup, there is no gender gap (and no unexplained gender gap). This result aligns with the logic of Ñopo's (2008) matching strategy: when individuals are truly comparable in both observable and unobservable characteristics, the labor market rewards them similarly.

This finding is significant for several reasons. First, it highlights the importance of controlling non-observable factors, such as family environment and early life conditions, which are often overlooked in traditional analyses. Second, it suggests that part of the unexplained wage disparities between men and women can be attributed to these unobservable variables — ultimately indicating that the unexplained gender gap could be smaller than generally estimated. Finally, the study underscores the utility of using twin studies to gain deeper insights into the mechanisms driving the gender pay gap, offering a robust methodological contribution to the field.

7. LIMITATIONS OF THE STUDY

Despite the advantages of the approach presented in this paper, it still has some limitations.

The biggest limitation is, in my view, that I could not investigate the impact of having children on the person's wage. This happened because the Brazilian database of individual's

IDs (the "CPF database", used to build the TwinsBR database) does not contain the father's name, only the mother's name. Therefore, it was not possible to determine fatherhood status for male individuals. It is possible that a part of the unexplained wage gap estimated in this work is due to the so-called Motherhood Penalty Gap. On the other hand, due to the fact that I am using a sample of young adults, it is likely that a significant part of my sample did not have children, so the error is likely to be minor.

A second limitation concerns the absence of information on marital status. Due to the lack of access to a unified national database on marriage in Brazil—and the prevalence of informal unions—it was not possible to account for whether individuals are married or cohabiting. This omission is relevant, as marital status can influence labor market outcomes. As noted by Averkamp et al. (2024), couples often make joint decisions about whose career to prioritize, which may affect wage trajectories in gendered ways.

Third, my study does not evaluate gender norms that could make even opposite-sex twins choose different careers and have different incomes.

Finally, due to the novelty of this approach, more work will be needed to delve deeper into the extent to which gender gap studies between twins of the opposite sex can help to understand the gender gap that exists in the job market in general.

A natural follow-up to this study would involve a two-stage estimation methodology. First, one could estimate the coefficients associated with each occupation and sector using the same-sex twins sample from TwinsBR. Then, these coefficients would be applied in a separate estimation involving opposite-sex twins to assess the impact of being female in this context.

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APPENDIX A. EXTRACTING THE UNEXPLAINED COMPONENT USING THE METHODOLOGY DEVELOPED BY BLINDER (1973) AND OAXACA (1973)

```
library(oaxaca)
#the dataframe ‘‘df’’ contains only opposite sex twins that are both in the labor market.
df<-subset(df,month=="December 2022")

results <- oaxaca(formula = log(h_wage) ~ tenure + contract_hours + idade_mae_no_parto +
mother_died_this_year +
has_disability + n_exits_last_3years + gdp_per_capita_year + age + age_squared + industry_A +
industry_B + industry_C +
industry_D + industry_E + industry_F + industry_G + industry_H + industry_I + industry_J +
industry_K + industry_L + industry_M + industry_N + industry_O + industry_P + industry_Q +
industry_R + industry_S + industry_T + occupation_cbo_administrative +

occupation_cbo_agriculture + occupation_cbo_armed + occupation_cbo_industrial +
occupation_cbo_repair + occupation_cbo_science + occupation_cbo_technician +
occupation_cbo_top + race_black + race_brown + race_indigenous + race_Not_informed +
race_yellow + uf_AC + uf_AL + uf_AM +
uf_AP + uf_BA + uf_CE + uf_DF + uf_ES + uf_GO + uf_MA + uf_MG + uf_MS + uf_MT +
uf_PA + uf_PB + uf_PE + uf_PI + uf_PR + uf_RJ +
uf_RN + uf_RO + uf_RR + uf_RS + uf_SC + uf_SE + uf_TO + nat_jur1d_Company +
nat_jur1d_Public_sector + level_education_1 + level_education_2 + level_education_3 +
level_education_4 + level_education_5 + level_education_6 + level_education_8 +
level_education_9 + level_education_10 + level_education_11 + tipo_Multiples +
tipo_OST + tipo_SST
| female
| industry_A + industry_B + industry_C +
industry_D + industry_E + industry_F + industry_G + industry_H + industry_I + industry_J +
industry_K + industry_L + industry_M + industry_N + industry_O + industry_P + industry_Q +
industry_R + industry_S + industry_T + occupation_cbo_administrative +
occupation_cbo_agriculture + occupation_cbo_armed + occupation_cbo_industrial +
occupation_cbo_repair + occupation_cbo_science + occupation_cbo_technician +
occupation_cbo_top + race_black + race_brown + race_indigenous + race_Not_informed +
race_yellow + uf_AC + uf_AL + uf_AM +
uf_AP + uf_BA + uf_CE + uf_DF + uf_ES + uf_GO + uf_MA + uf_MG + uf_MS + uf_MT +
uf_PA + uf_PB + uf_PE + uf_PI + uf_PR + uf_RJ +
uf_RN + uf_RO + uf_RR + uf_RS + uf_SC + uf_SE + uf_TO + nat_jur1d_Company +
nat_jur1d_Public_sector + level_education_1 + level_education_2 + level_education_3 +
level_education_4 + level_education_5 + level_education_6 + level_education_8 +
level_education_9 + level_education_10 + level_education_11 + tipo_Multiples +
tipo_OST + tipo_SST
,data = df, R = 100)
results$n results$y
results$twofold$overall
#repeat the procedure for all the years
```

APPENDIX B. SECOND APPENDIX

Table B.5 – Descriptive statistics for the full sample of pairs born on the same day and region

		Group	Dec 2019	Dec 2020	Dec 2021	Dec 2022
Number of pairs		Opposite-sex twins	7,697	7,709	9,500	9,260
		Random pair sample 1	1,537,208	1,544,489	1,934,932	1,887,430
		Random pair sample 2	1,536,151	1,543,430	1,934,233	1,886,259
Hourly Wage Difference in R$ (negative values= women earn less)	Normal Distribution? [1]	Opposite-sex twins	No	No	No	No
		Random pair sample 1	No	No	No	No
		Random pair sample 2	No	No	No	No
	Average	Opposite-sex twins	-1.81	-1.76	-1.89	-1.74
		Random pair sample 1	-0.94	-0.77	-0.94	-1.08
		Random pair sample 2	-0.94	-0.76	-0.94	-1.07
	Average smaller than OST? [2]	Random pair sample 1	No	No	No	No
		Random pair sample 2	No	No	No	No
	Median	Opposite-sex twins	-0.75	-0.64	-0.67	-0.82
		Random pair sample 1	-0.54	-0.42	-0.45	-0.47
		Random pair sample 2	-0.54	-0.41	-0.44	-0.47
	Variance	Opposite-sex twins	263.71	323.81	374.07	862.49
		Random pair sample 1	443.32	492.67	529.40	1237.61
		Random pair sample 2	441.68	493.15	531.01	1256.21
Gender Gap (negative values = women earn less)	Normal Distribution? [1]	Opposite-sex twins	No	No	No	No
		Random pair sample 1	No	No	No	No
		Random pair sample 2	No	No	No	No
	Average	Opposite-sex twins	7.47	10.93	11.94	23.11
		Random pair sample 1	31.07	36.34	34.99	48.56
		Random pair sample 2	31.07	36.35	34.97	48.58
	Average smaller than OST? [2]	Random pair sample 1	No	No	No	No
		Random pair sample 2	No	No	No	No
	Median	Opposite-sex twins	-8.79	-7.7	-7.57	-8.05
		Random pair sample 1	-6.55	-5.16	-5.36	-5.08
		Random pair sample 2	-6.51	-5.12	-5.29	-5.05
	Variance	Opposite-sex twins	9907.12	12235.43	15984.04	28233.90
		Random pair sample 1	27050.37	30909.13	30081.25	57596.52
		Random pair sample 2	26837.92	30559.69	30227.63	57809.50
Percentage of pairs where the woman earns more than the man		Opposite-sex twins	39.50	41.20	42.11	42.73
		Random pair sample 1	44.96	46.08	45.93	46.63
		Random pair sample 2	44.98	46.11	45.94	46.65

Source: author. Notes: [1] The Anderson-Darling test was the test applied for each of the twelve samples. The null hypotheses of a normal distribution were rejected at the 0.1% level for all samples. [2] A t test was performed. Even though the sample is not normally distributed, the t test is efficient in large samples.

APPENDIX C. RESULTS OF BO ESTIMATION FOR DECEMBER 2022

Table C.6 – Blinder Oaxaca estimation for December 2002 - sample with individuals born between 1986 and 2001, whose mother didn't have a namesake

Variable	**Male model** - Equation (2.5)	**Female model** - Equation (2.6)	**Difference in coefficients (male-female)**	**Conclusion: labor market "rewards this variable" more for...**
Intercept	2.3154***	2.4277***	-0.1124*	Women
Dummy: triplet or quadruplet birth	-0.0177	-0.0063	-0.0114	None
Dummy: is opposite-sex-twin	-0.0075*	-0.005	-0.0025	None
Dummy: is same-sex-twin	-0.0019	-0.0034.	0.0015	None
Tenure (in months)	0.0017***	0.0016***	0***	Man
Contract hours	-0.0146***	-0.0144***	-0.0002***	Women
Age of mother at childbirth	0.0001.	0.001***	-0.001***	Women
Mother died in current year	-0.0316***	-0.0306***	-0.0009	None
Has disability	-0.0719***	-0.0224***	-0.0495***	Women
Number of exits from jobs in the last 3 years	-0.0485***	-0.0407***	-0.0078***	Women
Age (in years)	0.0498***	0.0363***	0.0136***	Man
Age^2 (in years)	-0.0004***	-0.0003***	-0.0001***	Women
Race:black	-0.047***	-0.0434***	-0.0036*	Women
Race:brown	-0.0323***	-0.0277***	-0.0045***	Women
Race: Indigenous	-0.0676***	-0.0302***	-0.0374***	Women
Race: Not informed	-0.0467***	-0.0423***	-0.0045***	Women
Race:yellow	0.035***	0.0482***	-0.0132***	Women
Level of education: 1	-0.0739***	-0.0217***	-0.0521***	Women
Level of education: 2	-0.1163***	-0.1012***	-0.015**	Women
Level of education: 3	-0.1167***	-0.1006***	-0.0161***	Women
Level of education: 4	-0.0975***	-0.0932***	-0.0044.	None
Level of education: 5	-0.0808***	-0.069***	-0.0118***	Women
Level of education: 6	-0.0472***	-0.0407***	-0.0065***	Women
Level of education: 8	0.1081***	0.1177***	-0.0095***	Women
Level of education: 9	0.3661***	0.3354***	0.0307***	Man
Level of education: 10	0.6309***	0.6427***	-0.0117**	Women
Level of education: 11	0.7843***	0.7676***	0.0167**	Man
industry A	-0.3023***	-0.2677***	-0.0346	None
industry B	-0.0138	0.0581*	-0.0719	None
industry C	-0.2531***	-0.2341***	-0.019	None
industry D	0.0595.	0.0741**	-0.0146	None
industry E	-0.2756***	-0.1903***	-0.0853.	None
industry F	-0.3819***	-0.3032***	-0.0787.	None
industry G	-0.4119***	-0.3055***	-0.1064*	Women
industry H	-0.3197***	-0.2883***	-0.0314	None
industry I	-0.44***	-0.3506***	-0.0893*	Women
industry J	-0.3181***	-0.2382***	-0.0799.	None
industry K	-0.0942**	-0.07**	-0.0242	None
industry L	-0.4481***	-0.3597***	-0.0883*	Women
industry M	-0.3679***	-0.3074***	-0.0605	None
industry N	-0.4432***	-0.4***	-0.0432	None
industry O	-0.5265***	-0.526***	-0.0004	None
industry P	-0.5239***	-0.4764***	-0.0475	None
industry Q	-0.4462***	-0.3477***	-0.0985*	Women
industry R	-0.705***	-0.5325***	-0.1725***	Women

Variable	Male model - Equation (2.5)	Female model - Equation (2.6)	Difference in coefficients (male-female)	Conclusion: labor market "rewards this variable" more for...
industry S	-0.5001***	-0.4633***	-0.0368	None
industry T	-0.4633***	-0.4528***	-0.0105	None
Occupation: administrative	-0.0082***	0.0326***	-0.0408***	Women
Occupation: agriculture	-0.0007	-0.0284***	0.0277***	Man
Occupation: armed	0.283***	0.7398***	-0.4567***	Women
Occupation: industrial	0.0544***	0.0449***	0.0095***	Man
Occupation: repair	0.1583***	0.0273***	0.1311***	Man
Occupation: science	0.4287***	0.4495***	-0.0208***	Women
Occupation: technician	0.2087***	0.2139***	-0.0052***	Women
Occupation: top	0.3841***	0.4183***	-0.0342***	Women
State:AC	-0.1856***	-0.1781***	-0.0075	None
State:AL	-0.2844***	-0.3067***	0.0223***	Man
State:AM	-0.1942***	-0.1561***	-0.0381***	Women
State:AP	-0.1822***	-0.1205***	-0.0617***	Women
State:BA	-0.2282***	-0.2311***	0.0029.	None
State:CE	-0.2722***	-0.2593***	-0.0129***	Women
State:DF	-0.2052***	-0.0056***	-0.1996***	Women
State:ES	-0.1392***	-0.1723***	0.0331***	Man
State:GO	-0.1017***	-0.1383***	0.0366***	Man
State:MA	-0.2169***	-0.2426***	0.0257***	Man
State:MG	-0.1323***	-0.1678***	0.0355***	Man
State:MS	-0.0864***	-0.1212***	0.0348***	Man
State:MT	-0.0237***	-0.071***	0.0473***	Man
State:PA	-0.1898***	-0.1911***	0.0013	None
State:PB	-0.3293***	-0.3313***	0.0021	None
State:PE	-0.2446***	-0.25***	0.0055**	Man
State:PI	-0.3211***	-0.3424***	0.0213***	Man
State:PR	-0.0574***	-0.0765***	0.0191***	Man
State:RJ	-0.1244***	-0.1042***	-0.0201***	Women
State:RN	-0.2788***	-0.265***	-0.0138***	Women
State:RO	-0.1205***	-0.1355***	0.015***	Man
State:RR	-0.2471***	-0.2169***	-0.0302***	Women
State:RS	-0.0495***	-0.0686***	0.0191***	Man
State:SC	-0.0153***	-0.0277***	0.0125***	Man
State:SE	-0.2827***	-0.263***	-0.0197***	Women
State:TO	-0.1715***	-0.2134***	0.0418***	Man
Legal nature of job: company	-0.1289***	-0.1463***	0.0174***	Man
Legal nature of job: public sector	0.1547***	0.1962***	-0.0416***	Women
GDP per capita in the job's city	0***	0***	0***	Man
Number of observations	5,066,175	4,234,436	—	
Multiple R-squared:	0.4682	0.5244	—	
Adjusted R-squared:	0.4682	0.5244	—	
F-statistic:	5.373e+04 on 83 and 5066091 DF	5.625e+04 on 83 and 4234352 DF	—	
F-statistic (p-value)	less than 0.000001	less than 0.000001	—	
Jarque-Bera test: residuals are normal?	No (0.1%)	No (0.1%)		

Source: Author's calculations. Notes: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

3. PAPER 3

THE MOTHERHOOD PENALTY IN WAGES: AN ANALYSIS COMPARING BRAZILIAN TWIN FEMALES

Luiza Betina Petroll Rodrigues[39]

Department of Economics, University of Brasilia, Campus Universitario Darcy Ribeiro - FACE, Brasilia, DF 70910-900.

ABSTRACT

This study examines the impact of childbearing on the hourly wages of women, utilizing a comprehensive dataset of thousands of Brazilian same-sex female twins employed in the formal labor market. The analysis reveals that having children leads to a reduction in hourly wages by approximately 4% compared to their childless co-twins. This finding is significantly lower than previous estimates of the motherhood penalty in Brazil, indicating that the twin-based approach may offer a more precise measurement by accounting for unobservable factors.

Keywords: Motherhood penalty, wage gap, labor economics, gender economics, twin studies, childbearing, unobserved heterogeneity, Brazil, formal labor market, hourly wages
JEL Code: J13, J16, J31, J71.

RESUMO

Este estudo examina o impacto da maternidade sobre o salário por hora das mulheres, utilizando um conjunto de dados abrangente de milhares de gêmeas brasileiras do mesmo sexo empregadas no mercado de trabalho formal. A análise revela que ter filhos leva a uma redução no salário por hora de aproximadamente 4% em comparação com a irmã gêmea sem filhos. Esse valor é significativamente menor do que as estimativas anteriores da penalidade da maternidade no Brasil, indicando que a abordagem baseada em gêmeos pode oferecer uma medida mais precisa ao levar em conta fatores não observáveis.

1. INTRODUCTION

The motherhood penalty in wages, referring to the wage differences arising from having a child, is a well- documented phenomenon in labor economics. Numerous studies have consistently shown that women experience significant and persistent wage penalties after becoming mothers, a trend observed across various countries and time periods. Motherhood significantly impacts women's career trajectories and earnings potential (Grimshaw and Rubery, 2015), and it is possible that the long-term child penalty in earnings may explain a

[39] Corresponding author: luizabpr@gmail.com

substantial portion of the remaining gender wage gap (Kleven *et al*., 2019).

Despite the robust evidence on the existence of this penalty, measuring it accurately poses several methodological challenges. One major difficulty is the endogeneity of fertility choices, which complicates causal inference. Traditional approaches, such as event studies around the birth of the first child (like Kleven et al. , 2019), attempt to address this by leveraging high-quality panel data. However, these methods often struggle with sample selection issues.

This study utilizes a unique dataset of same-sex twins, the “TwinsBR” (Rodrigues, 2025), to compare the wages of women who have had children with their sisters who have no children in Brazil and were in the formal labor market in December of 2015 to 2022. The use of twin data offers significant methodological advantages. Twins share many genetic and environmental factors, allowing for a more precise control of unobserved heterogeneity. This design helps isolate the causal impact of having children on women’s earnings, providing more robust and generalizable findings.

I find that the female twin with children tends to earn around 4% less per hour compared to her co-twin who do not have children, and that this result did not change substantially between 2015 and 2022. The penalty is also similar for white and black/brown mothers. My estimates are lower than many other estimates of the motherhood penalty in Brazil.

By employing this twin-based approach, this study contributes to the literature on labor economics and gender economics in several ways. First, it is — to my knowledge — the first to replicate Simonsen and Skipper (2012)’s methodology on twins, and I replicate it in a developing country, Brazil, where the dynamics of the motherhood penalty gap may differ from those in high-income countries. Moreover, I use a much larger dataset (at least 6,310 pairs of females each year, compared to 290 pairs of Simonsen and Skipper (2012) sample). Second, my results suggest that previous estimates of the motherhood penalty in Brazil may be overestimated because they do not control for unobservable variables.

This paper is organized as follows. This section introduces the topic and outlines the main research questions. Section 2 provides a brief summary of the literature on the child penalty gap and discusses the methodological advantages and limitations of twin studies. Section 3 describes the econometric approach used in this study. Section 4 details the dataset, and Section 5 presents the findings. Finally, Section 7 summarizes and concludes the work.

2. RELATED LITERATURE

The term "Motherhood Penalty," also called "child penalty in females," refers to the disadvantages faced by mothers in the labor market, in addition to those associated with gender[40]. Kunde and Lourenço (2022), who provides a comprehensive summary of the academic literature on the theme, documents that this penalty can manifest in various ways, including lower wages, difficulties in hiring processes, limited opportunities for promotion and training, and even challenges in managing daily work routines. Nobel Prize winner Claudia Goldin's research has also shown that the birth of the first child significantly affects a woman's labor supply (Goldin, 2014).

Specifically, the term motherhood penalty in wages" or "motherhood pay gap" — hereafter MP for simplicity — measures the pay gap between mothers and non-mothers (Grimshaw and Rubery, 2015).

Extensively covered in the literature, MP is one of the most observable penalties. Research in this area suggests that mothers tend to earn lower salaries compared to women without children. These disadvantages are well- documented and highlight the systemic barriers that mothers face in their professional lives (Kunde and Lourenço, 2022). This is because, as women spend more time on family care, their participation in the labor market is hindered, and consequently, they receive lower wages. The choice of flexible occupations, as well as reduced working hours, are also pointed out by the authors as factors that can lead to lower salaries for women (Kunde and Lourenço, 2022, and Grimshaw and Rubery, 2015).

The seminal work of Kleven *et al*. (2019) highlights motherhood as a significant factor contributing to gender inequalities in the labor market. They proposed a methodology for calculating the motherhood penalty using event studies around the birth of the first child. This approach leverages high-quality panel data to capture the impact of childbearing on labor market outcomes. It compares the earnings trajectories of women before and after the birth of their first child. The analysis typically involves comparing the salary of women one year before the birth of the first child (t=-1) with their wages in the years following the child's birth. This methodology allows for a detailed examination of the immediate and long-term effects of motherhood on women's earnings, providing robust evidence of the persistent child penalty in various countries. Their methodology has been extensively used.

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[40] Some studies also analyze the "child penalty in males," like Kleven *et al*. (2019), but this is outside the scope of this work.

The issue of selection bias is a significant concern in studies measuring MP. As exemplified by Grimshaw and Rubery (2015), higher-educated women with greater earning potential may be less likely to have children, necessitating regression analyses that control for this bias. Kleven *et al*. (2019) provides a further example of the problem of selection bias: females from families with a traditional division of labor face larger child penalties when they become mothers. When these women are included in studies comparing mothers and non-mothers, the observed wage gap may be exaggerated because it reflects not only the impact of motherhood itself but also the influence of traditional family roles. This means that the wage differential attributed to motherhood might be confounded by pre-existing tendencies shaped by family background.

Grimshaw and Rubery (2015) delves deeply into methodological issues and mentions the use of various methodologies to deal with selection bias. Among these methodologies, comparison among twins is cited as one of the best solutions. In fact, using twins as a natural experiment to estimate the MP offers a compelling methodological approach[41]. This strategy leverages the inherent similarity between twins to control for unobserved heterogeneity, thus addressing selection bias. Specifically, comparing the labor market outcomes of twins where one has children and the other does not can provide robust estimates of the motherhood penalty. However, comparing twins is a rarely used methodology (Grimshaw and Rubery, 2015), because it requires access to register data.

Simonsen and Skipper (2012) had access to data on the entire population of employed same-sex twins in Denmark. In their estimation, they used a sample of 290 female twin pairs. In each pair, one was a mother and the other wasn't a mother in 2006. To my knowledge, this is the only work to employ the twin approach to uncover the effects of parenthood on wages for the general population.

Simonsen and Skipper (2012) made two regressions comparing the female twins, one using *normal hours*[42] to calculate hourly wages (i.e., they divided the wage by contract hours) and another using *actual hours*[43] to calculate hourly wages. When they used *normal hours*, they

[41] This is very different from studies that use twin births as an instrument. In these papers, females who had singletons are compared to females who had twins, because having twins is believed to be random and require extra work for the family. Using twins as a natural experiment, on the other hand, compares females who are twins in their labor market outcomes.

[42] Simonsen and Skipper (2012) provides the definition of OECD: normal hours of work are the hours of work fixed by or in pursuance of laws or regulations, collective agreements or arbitral awards, or the number of hours in excess of which any time worked is remunerated at overtime rates."

[43] According to Simonsen and Skipper (2012): Actual hours on the job are defined as normal hours minus hours

found that mothers earn on average 5.7% less than their co- twins — a statistically significant result. However, when they used *actual hours*, they found that the MP was smaller, around 2%, and not statistically significant. They conclude that the majority of the wage penalty for women can be explained when we account for higher rates of absence for mothers (which reduce actual hours). One way to interpret this result, the authors say, is that employers know that mothers are likely to be more absent than non-mothers (given the same number of normal hours) and they reward the two groups alike based on the number of hours they are actually present at the workplace.

Simonsen and Skipper (2012) results are notably lower than those calculated for the same country (Denmark) by Kleven et al. (2019). While Simonsen and Skipper (2012) found that mothers earn on average 5.7% less than their co-twins, Kleven et al. (2019) estimated that the child penalty on earnings for women amounts to around 20- 25% ten years after the birth of the first child. This significant difference may be partly due to unobservable factors, such as individual views on the importance of family versus work. The within-twin effect used by Simonsen and Skipper (2012) helps to control for these unobservable variables, potentially providing a more precise estimate of the motherhood penalty.

2.1. PREVIOUS WORKS ON MOTHERHOOD PENALTY IN BRAZIL

Gonçalves and Petterini (2023) provided a useful summary of studies on motherhood penalty around the world and mentioned that the few studies on the subject in Brazil have produced mixed or inconsistent results. Table 3.1 summarizes these works. None of them used identified twins in the sample.

absent due to sickness, holidays, etc., plus overtime."

Table 3.1- Recent works on motherhood penalty in Brazil

Work	de Medeiros (2022)	Cardoso (2024)	Gonçalves and Petterini (2023)	Petterini and Gonçalves (2024)
Description of the sample	Sample 1: women in formal labor market aged 18-30 years (from RAIS); sample 2: men and women aged 18-30 in formal and informal labor market (PNAD)	College-educated workers aged 15-65 years old, in private formal labor market	Women in formal labor market aged 20-39 years in 2008, working in the formal labor market, in the private sector, and who had only this child until 2018 (from RAIS)	A random sample of 5% of women between the ages of 20 and 39 who gave birth in 2008, and who had just one child until 2018.
Identification ıildbirth by	Sample 1: formal labor records; Sample 2: PNAD	formal labor records	formal labor records	formal labor records
Reference period	2007-2017	1995-2020	2005-2018	2005-2018
Methodology similar to	Kleven *et al.* (2019)	Kleven *et al.* (2019)	Kleven *et al.* (2019)	Kleven *et al.* (2019)
Calculated wage penalty	Sample 1: 5% in formal labor market; Sample 2: 5.7%.	Long term impact of 21.3%	Around 18% in the first year after childbirth to 29% after 10 years	Around 25% and 10% when the children are of infant and school age, respectively

Source: mentioned in the Table. Notes: [1] (B): In works that use the PNAD database, the motherhood/child- birth is assessed through the presence of sons/daughters in the household surveyed. [2] Some works also try to calculate the fatherhood penalty, but this is not the topic of this work, so these details are not in this table.

3. METHODOLOGY

This work follows Simonsen and Skipper (2012) closely by pairing same-sex twins females where one is a parent and the other is not, and defining the event of having children, C=1, while the "untreated" state of non-parenthood is defined as C=0. Motherhood is determined based on official registries, so it is possible that most of the female twins gave birth, while a small percentage may have adopted a child. In either case, C is equal to 1. Due to data limitations, it is not possible to verify if the child lives with the mother, but according to Census Data, this is the most common situation.

The wage of the non-parent twin female of family "j", $w_{1,j}$, can then be used as the counterfactual outcome for her co-twin who had children ($w_{2,j}$). Assuming linearity of the outcome equation but allowing for heterogeneous treatment effects, we get:

$$\ln(w_{i,j}) = \boldsymbol{X_{ij}\beta} + \theta_j \cdot C_{i,j} + [t_j + u_{i,j}] \quad (3.1)$$

where $\ln(w_{i,j})$ is the natural logarithm of the hourly wage for individual i=1,2 of family "j", adjusted for inflation using the CPI index "IPCA"; **X** is a matrix of variables believed not to be affected by parenthood (therefore, experience and occupation were excluded); t_j are unobserved twin-specific characteristics and $u_{i,j}$ are unobserved individual- specific characteristics.

In other words, this study employs a fixed-effects panel data model to analyze the impact of having a child on female wages. The primary advantage of using twins in this analysis is the ability to control for unobserved heterogeneity, such as genetic and familial factors, which are hypothesized to be very similar within twin pairs. This approach is common in twin studies (see Miller *et al.*, 1995, who studied the returns to education using twins).

The coefficient θ can then be estimated using fixed effects (or by differencing). The estimation of the model was conducted using the plm package in R, which is designed for panel data analysis. The model is estimated using the "within" transformation, which removes the individual fixed effects by demeaning the data. This transformation ensures that the estimates are not biased by unobserved heterogeneity.

4. DATA

This study uses *TwinsBR* (Rodrigues, 2025), a large Brazilian dataset of twins born between 1986 and 2001. The analysis focuses on all female twin pairs in which both individuals were alive in 2019, totaling 143,276 women (71,638 pairs), as shown in Figure 3.1. These women were born between 1986 and 2001, making them potential mothers of children born from 1996 onward. Excluding some individuals for lacking information, we start with 142,198 women (71,099 pairs).

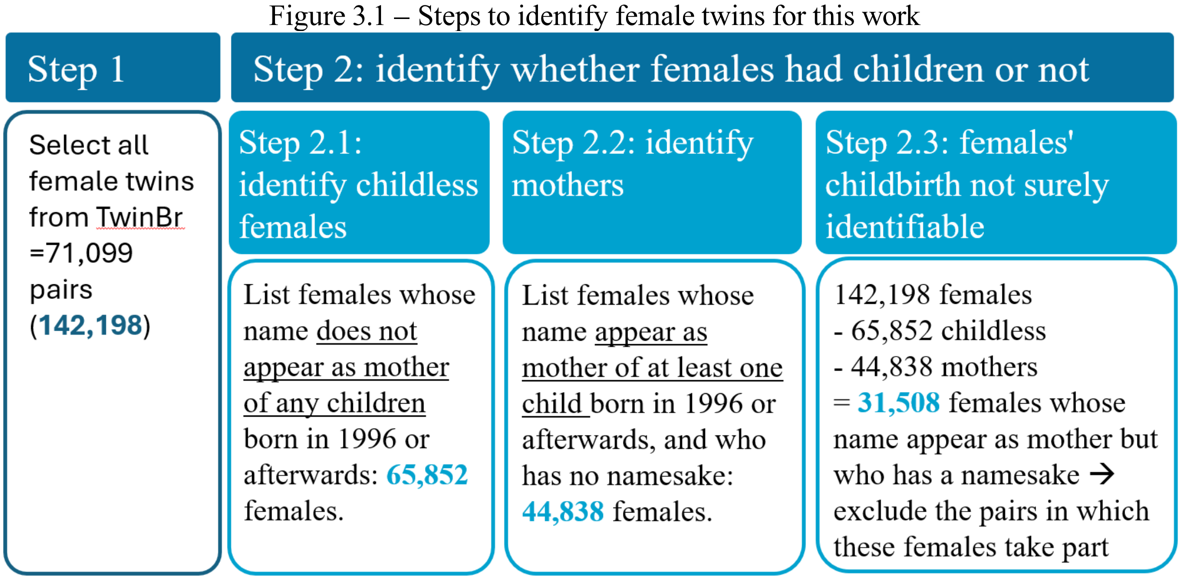
The next step was to determine whether each female had children. Unlike previous Brazilian studies that rely on labor registries to identify the first childbirth (see subsection 2.1), I used the CPF database. This approach has clear advantages, primarily the ability to capture childbirths of women not in the formal labor market. However, access to this database is restricted to a few researchers.

A woman was classified as childless if her name did not appear as the mother of any child born from 1996 onward in the CPF database. Even in cases of namesakes, if neither individual had children, the classification remained valid (both she and her namesake would be childless). This method is subject to minor errors due to name changes. For instance, if a woman had a child under one name and then changed her name due to divorce, she might be falsely identified as childless. This risk is limited, especially in a sample of young women: less than half of women in Brazil get formally married, and of those, less than half change their name (Arpen Brasil, 2023). Furthermore, about half of those who change their name get divorced, but not all divorces occur within the age cohort analysed (females aged 14 to 29 years in 2015, and aged 21 to 36 years in 2022). Overall, the likelihood of misclassification is low.

Next, I used the same technique employed by TwinsBr to identify women who can be definitively identified as mothers. For each year *t* (1996 or later), I identified female twins who had no namesake aged 10 to 59 years. If a name appeared as the mother of a child born in year *t*, and no namesake existed, the mother could be confidently identified as a twin in the sample.

Women whose names appeared as mothers but had namesakes could not be definitively identified. These cases, along with their twin pairs, were excluded. The final sample consists of 98,064 females (49,032 pairs), which remains large by twin study standards. This exclusion is unlikely to introduce bias, as the criterion — having a namesake — is likely to be relatively stable across age and income groups.

Figure 3.1 – Steps to identify female twins for this work

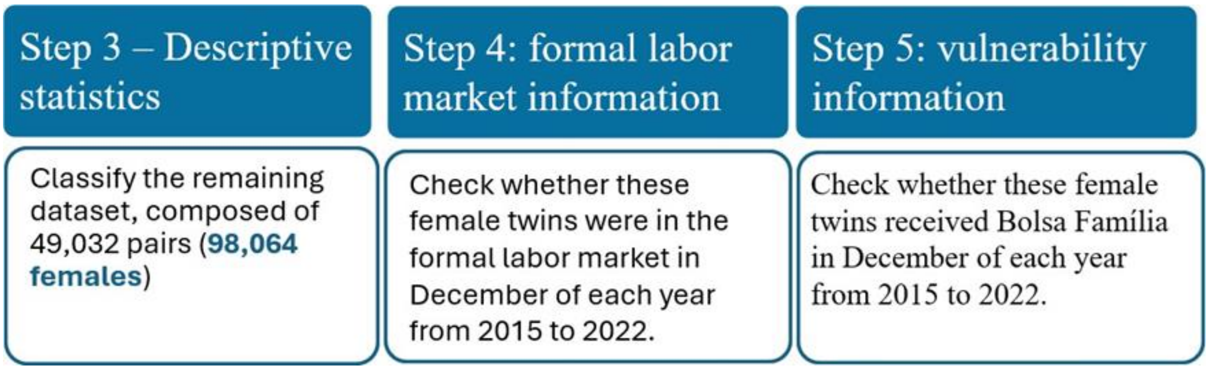


Source: author.

Figure 3.2 outlines the next steps: descriptive analysis and the collection of labor and vulnerability data. Formal employment data were obtained from RAIS, following Gonçalves and Petterini (2023) and Rodrigues (2025). Vulnerability data were drawn from Bolsa Família (BF) records in the CadÚnico database[44].

CadÚnico is particularly useful for capturing families outside the formal labor market. Linking CadÚnico with RAIS allows tracking of employment trajectories and financial stability among low-income women.

Figure 3.2 – Additional steps to create the database for this work



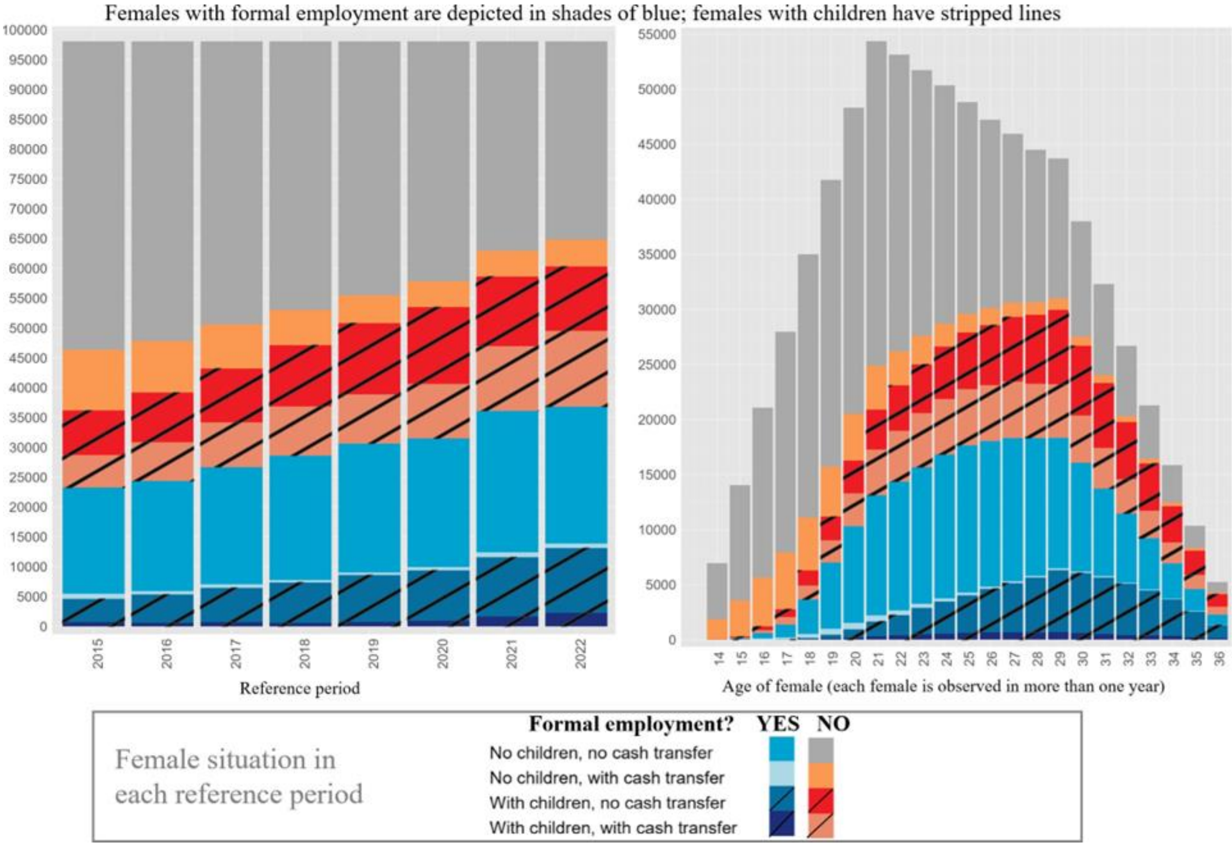
Source: author.

The remaining dataset, composed of 98,064 female twins (49,032 pairs), is detailed in Figure 3.3. In 2015, less than half of the females were in Formal Labor Registries or BF. This is due to two factors: first, the sample was very young (42% were under 20 years), so girls from middle class and high class, which do not receive BF, would be studying and not working. Second, the quality of labor data was not as good as it is today, and a portion of small companies did not report formal jobs that year (though they were obliged to do so).

In 2022, the situation changed. The sample aged, had children and either entered the labor market and/or started receiving cash transfer, and the quality of the data significantly improved.

Figure 3.3 – Number of observations of female twins in the database, by reference period and age

[44] The Cadastro Único (Cadúnico) is a comprehensive registry that allows the Brazilian government to identify and understand the living con- ditions of low-income families. Cadúnico serves as the foundation for several social programs. For instance, Bolsa Família, a conditional cash transfer program, uses Cadúnico to identify eligible families and distribute financial aid. The program aims to reduce poverty and promote social inclusion by providing monthly financial support to families living in extreme poverty.

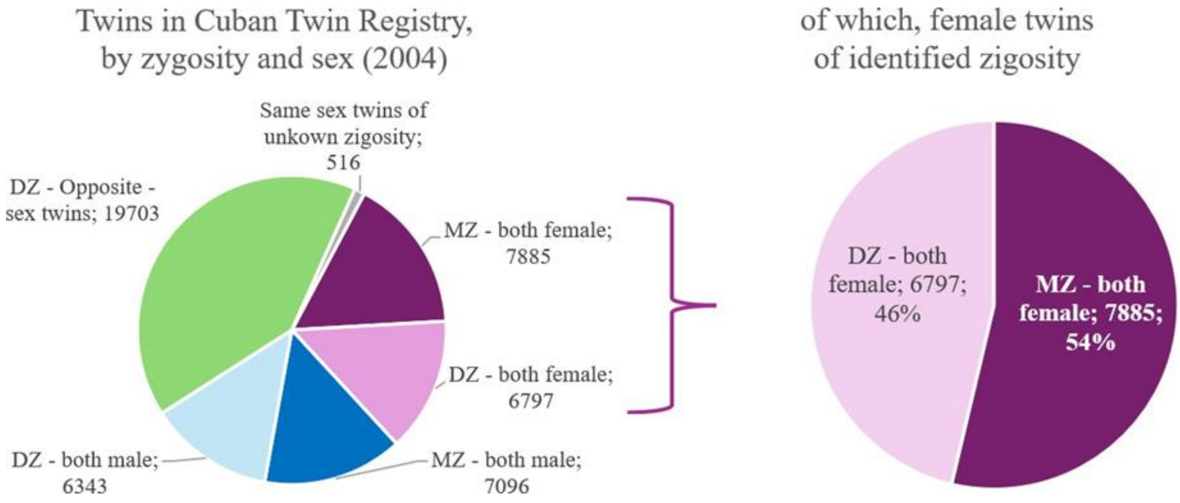


Source: author. "With cash transfer" means that the female belongs to a family that receives Bolsa Familia (BF), but does not mean that this female is the chief of the household. If the female is a teenager in 2015, for example, she (and her twin sister) is very likely to be living with their mother who is the chief of the household. In 2022, this same female may be a mother and receive BF as the chief of the household.

One important aspect of TwinsBR is that it has no zygosity information. This is a limitation because works that use only monozygotic (MZ or "identical" twins) are more comfortable in assuming the same genetic and family background. However, if we rely on the information provided by the Cuban Twin Registry (a population database made recently on a country that is racially similar[45] to Brazilian population), we can infer that, among female twins, 54% are monozygotic and 46% are dizygotic (see Figure 3.4). As monozygotic twins share 100% of genetic material and dizygotic (DZ) twins share on average 50%, we can hypothesize that, TwinsBr female twins share on average 77% of all genetic material, in addition to identical prenatal and family environments.

Figure 3.4 – Cuban Twin Registry: importance of monozygotic and dizygotic twins in pairs of female twins

[45] Race is an important aspect of the percentage of twin births.



Source: Marcheco-Teruel *et al*. (2013).

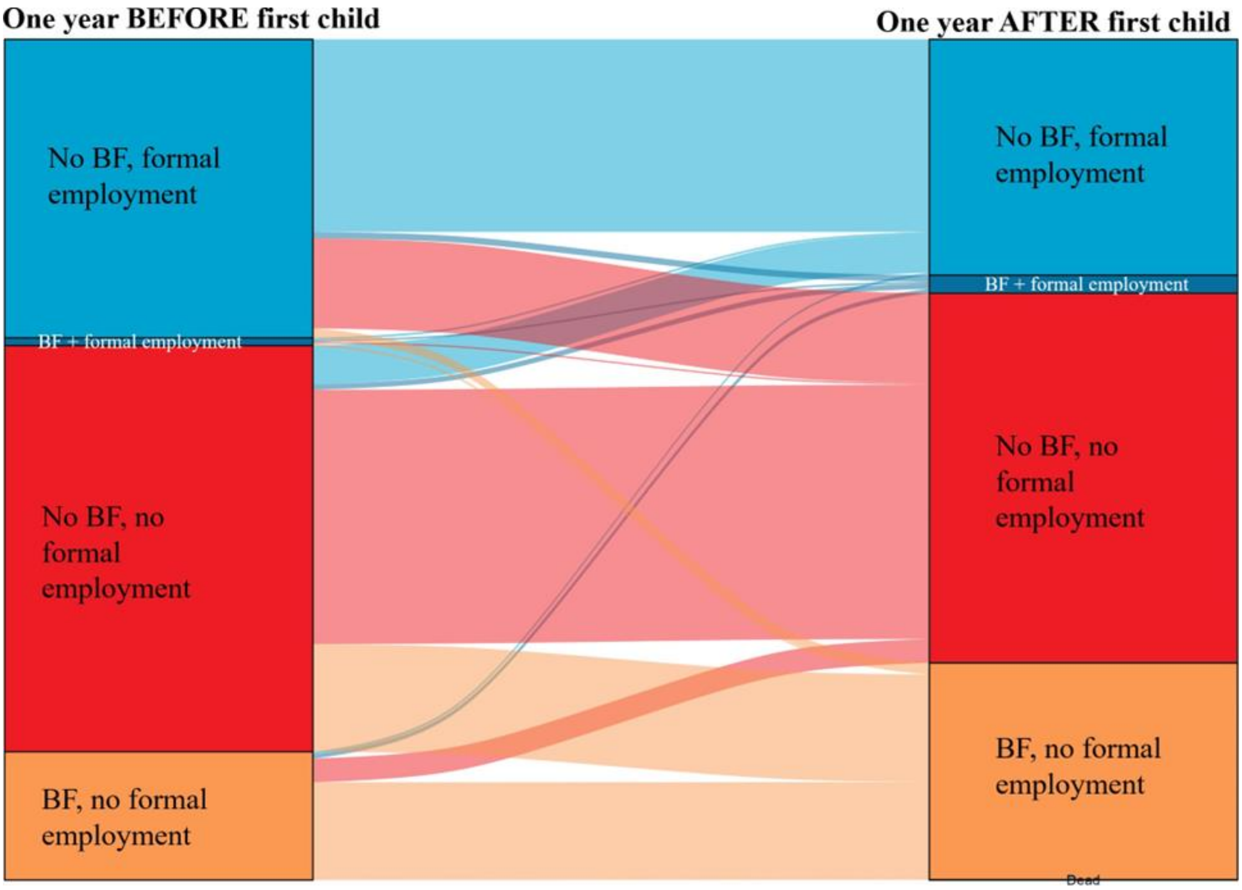
5. RESULTS

The first critical question in research on the motherhood penalty is: *What happens to young women after childbearing?* For the sample analyzed here, Figure 3.5 provides a clear picture. Most women remain in the same status as before childbirth — those previously employed in the formal sector or unemployed tend to stay in those conditions. However, two transitions stand out.

First, 33% of women who were formally employed leave their jobs after having a child. These women are typically not eligible for the Bolsa Família (BF) cash transfer program, suggesting that they exit the formal labor market and either rely on family income or shift to informal or autonomous work (i.e., they move from the blue to the red area in Figure 3.5).

Second, 26% of women who were previously outside the formal labor market and not receiving transfers (red area) become eligible for BF (orange area). Together, these shifts indicate that motherhood increases economic dependence — either on family members or on public transfers.

Figure 3.5 – Females before and after having their first child, by formal employment and Bolsa Familia (BF) cash transfer



Source: author. The sample included only females from TwinsBr, that is, females who are twins and who had their first child between 2016 and 2021. The number of distinct females analyzed totaled 16,570 females.

Among those who remain in formal employment, Figure 3.5 does not capture the adjustments women make to reconcile work and family responsibilities. These may include reducing contract hours, switching to lower-responsibility (and lower-paying) occupations, or declining roles that require overtime or travel.

To estimate the impact of motherhood on hourly wages, I estimate Equation (3.1) for each year in the sample. Controlling for years of schooling, city-level GDP per capita, and industry fixed effects, Equation (3.1) becomes:

$$\ln\left(w_{i,j}\right) = \beta_1 \cdot years\ of\ study + \beta_2 \cdot GDP\ per\ capita\ city + \text{industry dummies} + \theta_j \cdot C_{i,j} + \left[t_j + u_{i,j}\right] \quad (3.2)$$

Equation (3.2) is estimated for all female twins in the formal labor market, and separately by race, to assess whether the motherhood penalty varies across racial groups. As expected, *Years of Study* and *GDP per capita* are positively and significantly associated with wages in all specifications. The estimated coefficients for θ are presented in Table 3.2.

Table 3.2 shows that, for all years, the coefficient θ is negative and, except for 2016, statistically significant at the 1% level. Most estimates are close to -0.04, indicating that, on average, mothers earn 4% less per hour than their childless co-twins. This effect is roughly equivalent to the wage return of one additional year of education.

Table 3.2- Estimation of motherhood penalty using fixed-effects and Equation (3.2), for the full sample of female twins and by race

Ref. period	**All races**		Both females white		Both females brown or black		Is penalty on white and brown/ black women different? [c]
	$\hat{\theta}$ [a]	n [b]	$\hat{\theta}$ [a]	n [b]	$\hat{\theta}$ [a]	n [b]	
2015	**-0.0300***	6,310	-0.0413*	2,604	-0.0901***	1,049	No
2016	-0.0181	6,566	-0.0300.	2,707	0.0085	1,097	No
2017	**-0.0441*****	7,211	-0.0480**	2,903	-0.0256	1,172	No
2018	**-0.0428*****	7,691	-0.0337.	2,985	-0.0707**	1,298	No
2019	**-0.0445*****	8,042	-0.0340*	2,953	-0.0472*	1,359	No
2020	**-0.0493*****	8,313	-0.0263	2,956	-0.075*	1,401	No
2021	**-0.0313****	10,073	-0.0331.	3,181	-0.042	1,726	No
2022	**-0.0408****	10,222	-0.0328	3,013	-0.0519.	1,718	No

Source: author's. Notes: (a) [a] Signif. codes: 0 = '***'; 0.001 = '**' 0.01 = '*' 0.05 = '.' [b] "n" represents the number of pairs effectively used for estimation, that is, the pairs in which both female twins were in the formal labor market in the reference period. The number of pairs increases from 2015 to 2022 because the individuals who compose the sample age, and because the quality of data collected also improved in the period.;. [c] The coefficients were compared using the Wald test at a 5% significance level. "No" means we cannot reject the null hypothesis that the motherhood penalty is the same for white females and for black/brown females. A unilateral test was also performed, yielding the same result: the coefficients are statistically indistinguishable for white and black/brown pairs of twins. [d] In all cases, the F-statistic for the regression model is highly significant, with a p-value smaller than 0.00001. This indicates that the twin fixed effects are jointly significant. In other words, the model that includes twin fixed effects provides a significantly better fit to the data compared to a model without these effects.

Table 3.2 also suggests that the motherhood penalty is slightly larger among Black and Brown twins. However, the difference is not statistically significant when compared to White twins[46]. These results should be interpreted with caution. Although natural twinning rates are higher among individuals of African descent[47], Black and Brown women are underrepresented in the formal labor market[48]. Consequently, many black twin pairs in which only one sister is

[46] Results for yellow and indigenous twins were not computed due to the small sample.
[47] Natural twinning rates are higher across Central African region (Smits and Monden, 2011), and race/ethnicity is known to be a cause for different twinning rates.
[48] The participation rate of black/brown women is around 3 p.p. smaller than other women. Additionally, 43.3%

formally employed had to be excluded from the analysis. This reduced the effective sample size for this subgroup and may have limited the statistical power to detect significant differences.

6. CONCLUSIONS

The motherhood penalty is undeniable and can be found using various econometric methodologies. Mothers earn less than non-mothers in virtually every country. The motherhood penalty is an important part of gender pay gap.

However, the size of the estimated penalty differs across methodologies. Previous estimates of the motherhood penalty in Brazil indicate between 5.5% and 29% reduction in wages for mothers (see Section 2.1). These estimates were derived using the methodology proposed by Kleven *et al*. (2019). Our findings, using a within-twin methodology, suggest a lower penalty of around 4%, which may indicate that previous estimates were influenced by unobserved factors such as individual preferences and socio-economic conditions. By controlling for these unobservable variables, our approach offers a more accurate assessment of the true impact of childbearing on wages. The fact that within-twin estimates for motherhood penalty are lower than those estimated using Kleven *et al*. (2019)'s methodology had already happened when Simonsen and Skipper (2012) estimated it for Denmark (see Section 2).

This results suggests that a proper education for boys and girls, which provides not only skills for the labor market but also financial education and a comprehensive view on the costs and responsibilities of having a child, are likely to reduce motherhood penalty and gender pay gap. This is likely to happen both because men will be more likely to share child responsibilities but also because women will be more prepared to choose the best moment to have their children.

7. LIMITATIONS

This study has some limitations. The most important is the low participation of women in the formal labor market in Brazil. This contrasts sharply with Denmark, studied by Simonsen and Skipper (2012). As shown in Figure 3.5, many Brazilian women leave formal employment after having a child. This implies that studies based on formal labor data — including this one

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black/brown women works in informal jobs, against 32.7% of other women (Feijó, 2022). This provides a smaller population of black/brown females in formal jobs.

— may underestimate the true motherhood penalty. de Medeiros (2022) discusses this issue in detail. Future research could address this limitation by using alternative data sources, such as income flows through Pix, Brazil's instant payment system, to capture informal earnings.

A second limitation is related to sample composition. This study estimates the motherhood penalty only among women who have twin sisters. It is possible that women with sisters face a smaller penalty. When living in the same city, sisters may share childcare responsibilities. For example, a childless sister might help with school pickups or evening care. This type of support is less likely when the mother has only brothers — or no siblings at all. Therefore, the estimates may understate the penalty for the broader population of mothers. However, this bias is likely small. Most women rely on support from their own mothers or mothers-in-law and still experience a significant motherhood penalty.

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