

# Maternal Stress During Pregnancy and the Different Effects on Boys and Girls

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- **Fetal programming** is understood as the process by which the conditions of the environment in which pregnancy occurs affect full fetal development, with lasting consequences on physical and mental health and cognitive development throughout the life cycle (Glover, O'Connor and O'Donnell,2010)

- Stress during pregnancy is identified as a risk factor for full fetal development and consequences for child health and development (Torche, 2011; Currie and Rossin-Slater, 2013; Quintana-Domeque and Ródenas-Serrano, 2017);
- There is a gender dependency during fetal development, and this dependency is reflected in different sensitivities in the response to negative shocks (Sandman et al., 2013; Di Pietro and Voegtline, 2017; Sutherland and Brunwasser, 2019).

- Male fetuses invest more resources for their growth, which implies less reserve of resources and less ability to adjust to adversity;
- Female fetuses conserve resources and adjust better to adversity. However, girls are more vulnerable during childhood and adolescence, especially in behavioral and mental health issues.

This article aims to investigate how the effects of maternal stress during pregnancy have a different impact on the development of boys and girls throughout the life cycle.

# Theoretical Framework

## Fetal Programming

The hypothesis of fetal programming suggests that adverse events during the embryonic and fetal development stages cause irreversible changes in organs and metabolism, with long-term consequences, increasing the risk of diseases and developmental problems.

# Theoretical Framework

## Fetal Programming

The biological mechanisms involved in fetal programming are not fully understood; however, it is known that epigenetics plays an important role in this process.

Epigenetics is the term used to describe changes in gene expression without altering the DNA sequence. It is a field of biology that studies the interactions between genes and the environment in the production of the phenotype (phenotype = genotype + environment).



# Theoretical Framework

## Fetal Programming

Fetal programming refers to the plasticity of the human phenotype, partially shaped during the intrauterine period. These changes are recorded in the phenotype, carrying the adversities faced in the womb into the postnatal phase.

# Theoretical Framework

## Fetal Programming

Despite the primary focus of the literature on fetal programming being related to the increase in diseases in adulthood, there is also interest in understanding how the environment in which pregnancy occurs affects the individual's development in other dimensions, such as behavioral problems, academic and cognitive performance, and mental health.

# Theoretical Framework

## Sex dependence

Adverse effects impair the viability of boys early in life, increasing the likelihood of mortality and poor birth conditions. These same effects increase the probability of postnatal developmental problems in girls, particularly regarding behavioral and mental health issues.

# Theoretical Framework

## Gestational Period

- The gestational period in which the stressor event occurs is crucial for analyzing the effects of maternal stress on the offspring. Evidence suggests that the beginning and middle of pregnancy, the first and second trimesters, are the most sensitive.
- The increased sensitivity during the beginning and middle of pregnancy is due to the mother's reaction to stress, which decreases as pregnancy progresses, and to the pregnancy's developmental process.

- This paper contributes to the literature by discussing gender dependence on the effect of maternal stress during pregnancy and identifying the different periods in the life cycle in which negative impacts manifest themselves in boys and girls.
- As a contribution to the formulation of public policies, the paper shed some light on the need for specific health policies for boys and girls who were exposed to maternal stress in utero.

- Longitudinal study carried out in Chile where a representative sample of children for the whole country is followed during the first years of life.
- The survey, in addition to collecting socioeconomic information from the selected children's families, also conducted a series of assessments on the cognitive and non-cognitive development of the children and their primary caregivers and the children's birth outcomes.

## Challenges:

- Possible endogeneity of stress;
- To separate the effects in the uterus from possible post-birth effects;
- Endogeneity of birth date;
- Isolate the effect of stress from other problems caused by the earthquake.

- To avoid the possible endogeneity of maternal stress, the strategy is to use an exogenous event with a strong potential to induce stress.
- The exogenous event considered is Chile's February 27, 2010 earthquake.
- This earthquake was one of the five strongest ever recorded in history.



- To deal with the second challenge, the strategy is to compare children who were in the womb at the time of the earthquake with children between 0 and 9 months old.
- Therefore, post-earthquake events affect both groups, whereas only the treatment group is exposed to shock during pregnancy.

- Stress during pregnancy can change the length of pregnancy. As the treatment variable is defined based on the date of birth, this can lead to an endogeneity of the treatment variable.
- We use an instrumental variable with the theoretical time of pregnancy.

- To deal with the fourth challenge, some tests are used to verify possible alternative channels.
- In addition, we also verify in other sources of information that Chile is a country extremely prepared to deal with earthquakes.
- Therefore, measures to mitigate the problem and rebuild affected areas were so efficient that even the level of Human Development in the affected areas rose after the coping policies adopted by Chile.

**Treatment group:** children who were in the womb at the time of the earthquake and resided in areas affected by the earthquake.

**Control Group:** Children who were 0-9 months old at the time of the earthquake and residing in areas affected by the earthquake.

- To prevent the results found in the estimates from being influenced by the child's age, all development measures were standardized for each month of children's age.
- Standardization was performed with all children in the sample, while estimations were performed only for children who were born in areas affected by the earthquake.

**Tabela: Birth Outcomes**

	Birthweight	Low birthweight	Size at birth	Gestation length	Weight/length	Size/length
Panel A - Full Sample						
Pregnancy	-0,0971**	0,0242*	-0,1732	-0,1613	-0,0021**	0,0011
1° Trimester	-0,1309**	0,0082	-0,4998*	-0,2493	-0,0028**	-0,0035
2° Trimester	-0,1506***	0,0254	-0,3400	-0,2141	-0,0033***	0,0018
3° Trimester	-0,0150	0,0383	0,3100	-0,0262	-0,0004	0,0051
Observations	774	774	748	774	774	748
Panel B - Boys						
Pregnancy	-0,1062**	0,0211	-0,3603	-0,0716	-0,0026*	-0,0068
1° Trimester	-0,1672**	0,0136	-0,9375**	-0,3624	-0,0034	-0,0105
2° Trimester	-0,1942***	0,0252	-0,4295*	-0,0379	-0,0048***	-0,0075
3° Trimester	0,0347	0,0230	0,2439	0,1561	0,0004	-0,0024
Observations	388	388	375	388	388	375
Panel C - Girls						
Pregnancy	-0,1041*	0,0335	-0,0518	-0,1908	-0,0022	0,0048
1° Trimester	-0,1065	0,0143	-0,0334	-0,1840	-0,0023	0,0050
2° Trimester	-0,1335*	0,0342	-0,5112*	-0,3927	-0,0024	0,0042
3° Trimester	-0,0747	0,0557	0,3724	-0,0166	-0,0019	0,0050
Observations	386	386	373	386	386	

# Results

## Second Wave (2/3 years old)

**Tabela: Second Wave**

	Socioemotional			Learning and Development				
	Total	Internalizing	Externalizing	Total	SE	Language	Motor	Cognitive
Panel A - Full sample								
Pregnancy	0,1083	0,0923	0,1104	-0,0863	-0,0220	0,0175	-0,0992	-0,1457*
1° Trimester	0,1255	0,1287	0,1414	-0,1333	0,0009	0,0068	-0,1012	-0,2843***
2° Trimester	0,0391	0,0083	0,0896	0,0251	0,0379	0,0894	-0,0435	-0,0322
3° Trimester	0,1499	0,1285	0,0966	-0,1376	-0,0961	-0,0352	-0,1440	-0,1079
Observations	765	765	767	762	767	764	766	766
Panel B - Boys								
Pregnancy	0,0910	0,0873	0,0540	-0,1189	-0,0665	-0,0087	-0,0776	-0,1515
1° Trimester	0,3062	0,2486	0,2771	-0,2791**	-0,1409	-0,2318*	-0,0733	-0,3124*
2° Trimester	-0,1621	-0,1190	-0,1390	0,1217	0,0790	0,2738	-0,0329	0,0327
3° Trimester	0,1332	0,1332	0,0363	-0,1923	-0,1289	-0,0668	-0,1182	-0,1711
Observations	384	384	386	382	385	384	384	384
Panel C - Girls								
Pregnancy	0,1418	0,1139	0,1738*	-0,0509	0,0240	0,0497	-0,1261	-0,1246
1° Trimester	0,0173	0,0517	0,0946	0,0207	0,1648	0,2118	-0,1002	-0,2426
2° Trimester	0,3319*	0,2580	0,3549**	-0,0400	0,0230	-0,0912	-0,0057	-0,0392
3° Trimester	0,1241	0,0607	0,1080	-0,1512	-0,1533	-0,0241	-0,2707**	-0,0548
Observations	381	381	381	380	382	380	382	382



# Results

Third Wave (8/9 years old)

Tabela: Third Wave

	Total	Socioemotional		Cognitive skills		
		Internalizing	Externalizing	Applied problems	Math skills	Calculus
Panel A - Full sample						
Pregnancy	0,0071	-0,0174	0,0082	-0,0462	-0,0510	-0,0468
1° Trimester	0,0311	-0,0565	0,0714	-0,0512	0,0210	-0,0043
2° Trimester	-0,2010**	-0,1760**	-0,2066***	-0,1550	-0,1680	-0,2292**
3° Trimester	0,1626	0,1565	0,1320	0,0545	-0,0176	0,0736
Observations	773	773	773	771	770	770
Panel B - Boys						
Pregnancy	-0,0303	-0,0803	-0,0453	-0,0577	0,0069	-0,0477
1° Trimester	0,0832	-0,0712	0,1320	-0,0193	0,1198	-0,0240
2° Trimester	-0,2920***	-0,2978**	-0,2860***	-0,2111	-0,0565	-0,2196
3° Trimester	0,1053	0,1069	0,0177	0,0523	-0,0352	0,0957
Observations	388	388	388	385	384	384
Panel C - Girls						
Pregnancy	0,0548	0,0226	0,1011	-0,0334	-0,1471	-0,0491
1° Trimester	0,0071	-0,0569	0,0638	-0,0516	-0,0306	-0,0097
2° Trimester	-0,0756	0,0016	-0,0984	-0,1463	-0,3857**	-0,2266
3° Trimester	0,2293	0,1390	0,3244*	0,0889	-0,0788	0,0598
Observations	385	385	385	386	386	386



# Results

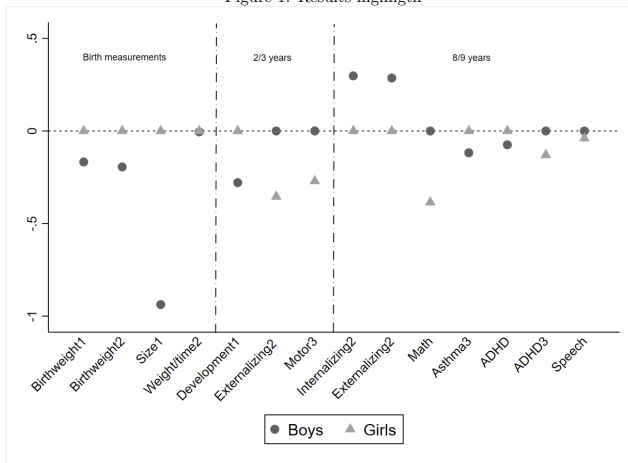
Health (8/9 years old)

Table 4: Health

	Asthma	ADHD	Speech difficulties
Panel A - Entire sample			
Pregnancy	0,0183	0,0683***	0,0033
1 <sup>o</sup> Trimester	-0,0232	0,0463*	0,0043
2 <sup>o</sup> Trimester	-0,0058	0,0429	-0,0180
3 <sup>o</sup> Trimester	0,0796*	0,1108***	0,0213
Observations	773	769	770
Panel B - Boys			
Pregnancy	0,0508	0,0747**	-0,0296
1 <sup>o</sup> Trimester	-0,0031	0,0862*	-0,0394*
2 <sup>o</sup> Trimester	0,0280	0,0627	-0,0292
3 <sup>o</sup> Trimester	0,1178**	0,0729	-0,0201
Observations	388	386	386
Panel C - Girls			
Pregnancy	-0,0152	0,0445	0,0394**
1 <sup>o</sup> Trimester	-0,0357	0,0095	0,0486
2 <sup>o</sup> Trimester	-0,0478	-0,0039	-0,0041
3 <sup>o</sup> Trimester	0,0387	0,1298**	0,0676*
Observations	385	383	384

Note: Level of significance \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01

Figure 1: Results highlight



# Alternative Channels

Table 5: Alternative Channels

	Prenatal	Type of delivery
Panel A - Entire sample		
Pregnancy	0,0239	0,0233
1 <sup>o</sup> Trimester	-0,0450	0,0311
2 <sup>o</sup> Trimester	0,1017**	0,0212
3 <sup>o</sup> Trimester	0,0198	0,0171
Observations	759	774
Panel B - Boys		
Pregnancy	-0,0370	0,0240
1 <sup>o</sup> Trimester	-0,1568	0,0857
2 <sup>o</sup> Trimester	0,0307	0,0071
3 <sup>o</sup> Trimester	0,0057	-0,0155
Observations	382	388
Panel C - Girls		
Pregnancy	0,0781	0,0250
1 <sup>o</sup> Trimester	0,0598	-0,0390
2 <sup>o</sup> Trimester	0,1681**	0,0601
3 <sup>o</sup> Trimester	0,0192	0,0691
Observations	377	386

Note: Level of significance \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01

# Indirect Effects of Stress

Table 6: Mother's health during pregnancy

	Preeclampsia	Urinary infection	Bleeding	Hypertension	Pla previa	Diabetes	Anemia
Panel A - Entire sample							
Pregnancy	-0,0069	0,0389	0,0202*	-0,0043	0,0201	-0,0014	-0,0504*
1 <sup>o</sup> Trimester	-0,0133	0,0391	0,0129	0,0186	0,0335	-0,0011	-0,0664**
2 <sup>o</sup> Trimester	0,0084	0,0129	0,0383	-0,0096	0,0053	-0,0220	-0,0604
3 <sup>o</sup> Trimester	-0,0141	0,0611	0,0108	-0,0217	0,0197	0,0167	-0,0249
Observations	774	774	774	774	774	774	774
Panel B - Boys							
Pregnancy	-0,0087	0,0187	-0,0038	0,0062	0,0199	-0,0137	-0,0159
1 <sup>o</sup> Trimester	-0,0003	0,0427	-0,0225**	0,0394	0,0336	0,0161	-0,0382
2 <sup>o</sup> Trimester	0,0042	0,0161	0,0233	0,0267	0,0169	-0,0461	-0,0095
3 <sup>o</sup> Trimester	-0,0279**	-0,0007	-0,0126	-0,0426**	0,0098	-0,0089	-0,0017
Observations	388	388	388	388	388	388	388
Panel C - Girls							
Pregnancy	-0,0071	0,0668*	0,0478***	-0,0177	0,0183	-0,0058	-0,1009**
1 <sup>o</sup> Trimester	-0,0267*	0,0321	0,0529**	-0,0062	0,0388	-0,0093	-0,0874
2 <sup>o</sup> Trimester	0,0071	0,0362	0,0534	-0,0311	-0,0175	-0,0070	-0,1386**
3 <sup>o</sup> Trimester	0,0032	0,1356**	0,0366	-0,0192	0,0262	-0,0006	-0,0828
Observations	386	386	386	386	386	386	386

Note: Level of significance \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

# Indirect Effects of Stress

Table 7: Mother's behavior during pregnancy

	Malnutrition	Cigarettes	Alcohol	Alc very	Alc not very	Drugs
Panel A - Entire sample						
Pregnancy	0,0222	0,0166	0,0310	0,0109	0,0201	-0,0056
1 <sup>o</sup> Trimester	0,0389	-0,0131	0,0170	-0,0008	0,0178	-0,0044
2 <sup>o</sup> Trimester	0,0344	0,0054	0,0909**	0,0082	0,0827**	-0,0157**
3 <sup>o</sup> Trimester	-0,0053	0,0551	-0,0094	0,0243	-0,0337	0,0024
Observations	774	774	774	774	774	773
Panel B - Boys						
Pregnancy	0,0019	0,0153	0,0306	0,0086	0,0220	-0,0050
1 <sup>o</sup> Trimester	0,0243	-0,0425	-0,0239	-0,0040	-0,0198	-0,0131
2 <sup>o</sup> Trimester	0,0217	0,0391	0,0749	0,0156	0,0594	-0,0106
3 <sup>o</sup> Trimester	-0,0366	0,0434	0,0358	0,0130	0,0228	0,0076
Observations	388	388	388	388	388	388
Panel C - Girls						
Pregnancy	0,0325*	0,0108	0,0335	0,0106	0,0229	0,0010
1 <sup>o</sup> Trimester	0,0397	0,0022	0,0532	0,0027	0,0505	-0,0002
2 <sup>o</sup> Trimester	0,0308	-0,0362	0,1075*	-0,0057	0,1131*	-0,0158
3 <sup>o</sup> Trimester	0,0256	0,0633	-0,0567**	0,0348	-0,0914***	0,0175
Observations	386	386	386	386	386	385

Note: Level of significance \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01

# Mother's Mental Health after Childbirth

Table 8: Mother's mental health after childbirth

	Postpartum depression	Stress 2012	Stress 2017	Depression 2017
Panel A - Entire sample				
Pregnancy	0,0018	-0,2234	-0,0277	-0,0529
1 <sup>o</sup> Trimester	0,0714	0,4110	0,0213	-0,1084**
2 <sup>o</sup> Trimester	-0,0559*	-0,3309	-0,0624	-0,0439
3 <sup>o</sup> Trimester	-0,0130	-0,7371	-0,0437	-0,0062
Observations	768	773	773	773
Panel B - Boys				
Pregnancy	-0,0096	0,5602	0,0714	-0,1056*
1 <sup>o</sup> Trimester	0,0692	1,4731	0,1025	-0,1168*
2 <sup>o</sup> Trimester	-0,0743	0,5949	0,0474	-0,0979
3 <sup>o</sup> Trimester	-0,0144	-0,2996	0,0639	-0,0991
Observations	384	388	388	388
Panel C - Girls				
Pregnancy	0,0229	-0,9222	-0,1231	-0,0009
1 <sup>o</sup> Trimester	0,0929	-0,6244	-0,0533	-0,0919*
2 <sup>o</sup> Trimester	-0,0316	-1,1201	-0,1858	0,0104
3 <sup>o</sup> Trimester	-0,0103	-1,0965	-0,1493	0,0970
Observations	384	385	385	385

Note: Level of significance \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01

# Final Remarks

- The paper investigates gender dependence in the reaction to maternal stress during pregnancy;
- Boys show greater sensitivity in birth measurements, whereas the effects on girls are more clearly perceived in the first years of life;
- As a contribution to the formulation of public policies, the paper highlights the importance of actions to alleviate post-traumatic stress in pregnant women and differentiated healthcare actions for boys and girls who have been exposed to stress in utero.

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