Estimating Difference-in-Differences in the Presence of Spillovers

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This Paper

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Motivation

Difference-in-differences in Economics

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- Consistency relies on the Stable Unit Treated Value Assumption (SUTVA)
- Much recent discussion within and outside of academics (eg “The Worm Wars”)

Teenage Pregnancy in Latin America

Rates of teenage pregnancy in Latin America are very high by world standards, although considerable variation by country

- In Latin America, between the ages of 15-19, 67 in 1,000 women will give birth
- In Chile, this figure is 55 in 1,000 and in Mexico 62 per 1,000
- High income countries often have rates of between 2 and 10 per 1,000

Figure 1 : Adolescent Pregnancy Rates in Latin America and the World

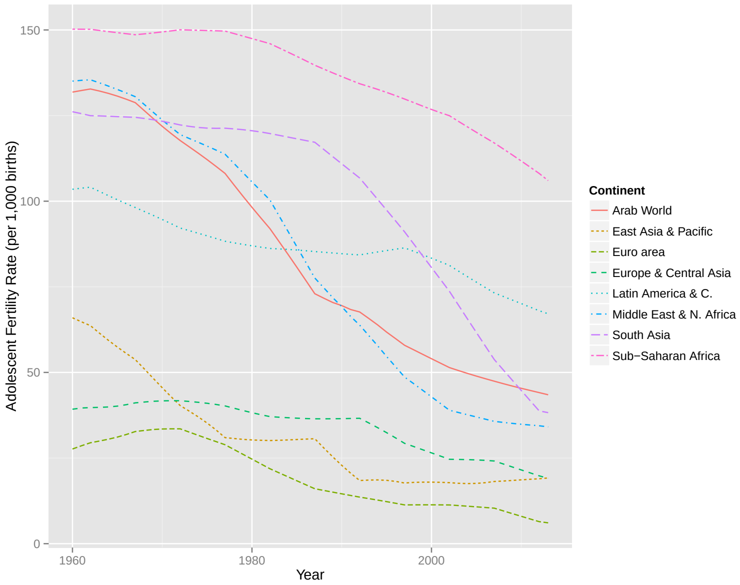
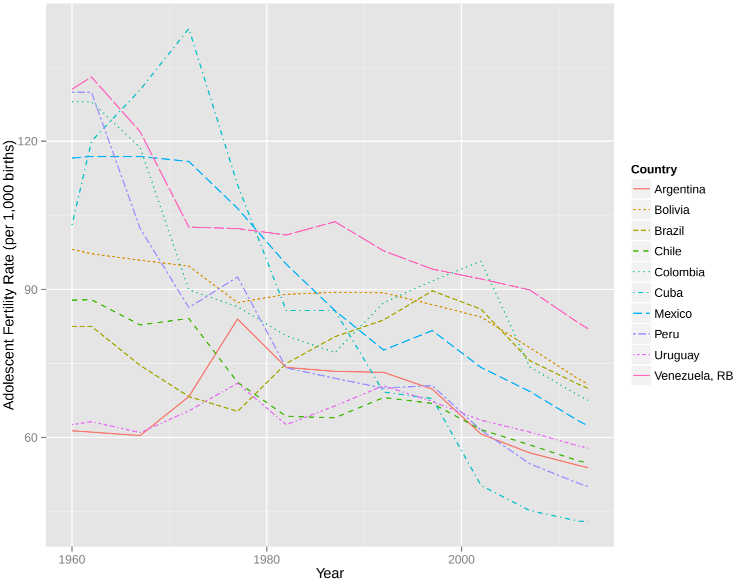


Figure 2 : Adolescent Pregnancy Rates in Various Latin American Countries



Teenage Pregnancy

Teenage pregnancy has been shown to be

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Methodology

"Typical" diff-in-diff where outcome is generated by components of variance process (Ashenfelter and Card, 1985):

$$Y(i,t) = \delta(t) + \alpha D(i,t) + \eta(i) + \nu(i,t), \tag{1}$$

and estimand of interest is:

$$\begin{aligned} \alpha &= \{E[Y(i,1)|D(i,1)=1] - E[Y(i,1)|D(i,1)=0]\} \\ &\quad -\{E[Y(i,0)|D(i,1)=1] - E[Y(i,0)|D(i,1)=0]\} \end{aligned} \tag{2}$$

Methodology

This relies on a binary measure of treated versus non-treated. In this paper, I generalise this. Consider:

$$Y(i,t) = \delta(t) + \alpha D(i,t) + \beta R(i,t) + \eta(i) + \nu(i,t) \tag{3}$$

where

$$R(i,t) = \begin{cases} f\Big(X(i,t)\Big) > 0 & \text{if close to, but not in, treatment area} \\ 0 & \text{otherwise} \end{cases}$$

Methodology

- Here $X(i,t)$ is an observed measure of 'distance'
- And $f(\cdot)$ is a positive monotone function
- However, $R(i,t)$ is not observed given that "close" is subjective

Methodology

And this leads to two estimands:

$$\begin{aligned}\alpha \quad &= \{E[Y(1)|D(1)=1, R(1)=0] - E[Y(1)|D(1)=0, R(1)=0]\}\\ &- \{E[Y(0)|D(1)=1, R(1)=0] - E[Y(0)|D(1)=0, R(1)=0]\},\end{aligned}$$

$$\begin{aligned}\beta \quad &= \{E[Y(1)|D(1)=0, R(1)\neq 0] - E[Y(1)|D(1)=0, R(1)=0]\}\\ &- \{E[Y(0)|D(1)=0, R(1)\neq 0] - E[Y(0)|D(1)=0, R(1)=0]\}.\end{aligned}$$

where i has been supressed for ease of exposition.

Estimation

In this paper I am interested in estimating the unbiased causal effects α and β. This is referred to as a "spillover robust double differences estimator"

- This allows for spillovers, without imposing that they must exist
- More importantly, if spillovers do exist, this corrects for potential confounding effects of including "close" units in the control group

Estimation

In a Rubin (1974) causal framework, $Y^1(i, t)$ is the potential outcome for some person i at time t if they were to receive treatment, and $Y^0(i, t)$ if the person were not to receive treatment.

- The fundamental challenge of inference is that only one of these is observed
- Inference then proceeds using expectations over groups
- Unbiasedness relies on parallel trend assumptions holding

Estimation

Hence, I define:

$$ATT = E[Y^1(i,1) - Y^0(i,1)|D(i,1) = 1] \tag{4}$$
$$ATC = E[Y^1(i,1) - Y^0(i,1)|C(i,1) = 1], \tag{5}$$

where $C(i,t)$ refers to close, and is simply a re-definition of $R(i,t)$: $C(i,t) = \mathbf{1}_{R(i,t)\neq 0}$

ATT Average treatment effect on the treated

ATC Average treatment effect on the close to treated

These are the sample counterparts of α and β, the population estimands of interest.

Estimation

Unbiasedness relies on a number of assumptions.

1. Parallel trends in treatment and control

$$E[Y^0(1) - Y^0(0)|D(1) = 1, C(1) = 0] =$$
$$E[Y^0(1) - Y^0(0)|D(1) = 0, C(1) = 0]$$

2. Parallel trends in close and control

$$E[Y^0(1) - Y^0(0)|D(1) = 0, C(1) = 1] =$$
$$E[Y^0(1) - Y^0(0)|D(1) = 0, C(1) = 0]$$

Estimation

This is the fundamental diff-in-diff identifying assumption of parallel trends, generalised to hold for treatment *and* close to treatment status

- However, note that we no longer need to make *any* assumptions regarding parallel trends between treatment and close to treatment units
- This allows for direct interactions of any form between those living in treatment areas, and those living close by
- This loosens SUTVA, however, as a matter of course, some reduced form of SUTVA must be assumed for causal estimates

Estimation

3. SUTVA holds for some units

There is some subset of individuals $j \in J$ of the total population $i \in N$ for whom potential outcomes (Y_j^0, Y_j^1) are independent of the treatment status $D = \{0, 1\}$ $\forall_{i \neq j} \in N$.

This loosens SUTVA in the sense that here it must hold only between *some* units. Identification relies on there existing at least some subset of units which are not affected by the treatment status of others.

Estimation

Finally, it is assumed that spillovers, or violations of SUTVA, do not occur randomly in the population

4. Assignment to close to treatment depends on observable X

There exists an assignment rule $\delta\Big(X(i,t)\Big) = \{0,1\}$ which maps individuals to close to treatment status $C(i,t)$, where $\delta\Big(X(i,t)\Big) = \mathbf{1}_{X(i,t)<d}$, $X(i,t)$ is an observed covariate, and d is a fixed scalar cutoff.

Estimation

This is quite demanding. It requires that spillovers be based on an observable and unidimensional factor (though of arbitrary functional form)

- In some cases this may be acceptable (ie physical distance)
- In other cases, we will be interested in extending this to allow for multidimensional determinants, or interactions between distance and individual characteristics
- A multidimensional (non-parametric) extension of this methodology is provided in the paper

Estimation

Proposition 1

Under assumptions 1 to 4, the ATT and ATC can be consistently estimated by least squares when controlling, parametrically or non-parametrically, for $C(i,t) = \mathbf{1}_{X(i,t) \leq d}$.

Estimation

Empirical Application

In order to examine this empirically, we need:

1. A sharply defined policy reform over space and time
2. A treatment group and control group seperated by geographic boundaries
3. Members of the treatment group with sufficient incentives to violate their status, travelling to (or otherwise managing to access) the reform

Empirical Application

As such, we focus on two recent contraceptive reforms:

1. **Chile** 2008 reform: The emergency contraceptive pill
2. **Mexico** April 26, 2007: Legal interruption of pregnancy (ILE)

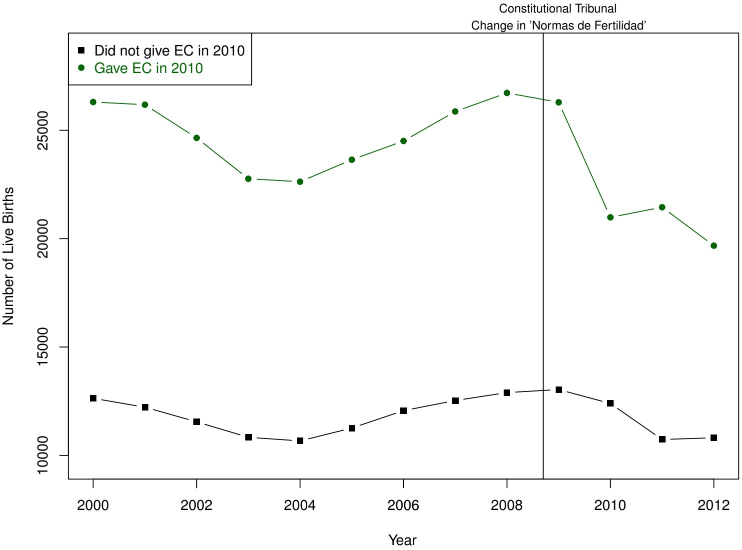
These reforms work well: the costs of not having access (undesired pregnancy) are very high, and geographic boundaries (comunas, municipios) can be crossed easily

Empirical Application 1: Emergency Contraceptive Pill in Chile

In 2008, following years of constitutional challenges, the decision of whether or not to prescribe the morning after pill was left in the hand of the mayor of each comuna in Chile

- This was codified in the *Normas Nacionales sobre Regulación de la Fertilidad*
- I collect data on all births (DEIS), population (INE) and whether the morning after pill was prescribed by comuna (Dides et al.)
- Further details and descriptives provided in Bentancor and Clarke (2014) and Casas Becerra (2008)

Figure 3 : Trends in Teenage Pregnancy (Chile)



Note: Some municipalities which did not give the EC pill in 2010 did give the EC pill in 2011 (and vice versa).

Table 1 : Treatment Effects and Spillovers: Chile (15-19 year olds)

	Pr(Birth) (1)	Pr(Birth) (2)	Pr(Birth) (3)	Pr(Birth) (4)	Pr(Birth) (5)
Treatment	-0.046^{***}	-0.058^{***}	-0.066^{***}	-0.073^{***}	-0.074^{***}
	(0.011)	(0.013)	(0.014)	(0.014)	(0.015)
Close 1		-0.049^{***}	-0.056^{***}	-0.062^{***}	-0.062^{***}
		(0.015)	(0.014)	(0.014)	(0.014)
Close 2			-0.040^{*}	-0.047^{*}	-0.048^{**}
			(0.023)	(0.024)	(0.024)
Close 3				-0.038^{*}	-0.038^{*}
				(0.023)	(0.023)
Close 4					-0.014
					(0.023)
Mean	0.052	0.052	0.052	0.052	0.052
Regions× Time	1,929	1,929	1,929	1,929	1,929

NOTES: Each column represents a separate difference-in-differences regression including full time and municipal fixed effects and linear trends by municipality. Standard errors are clustered at the level of the geographic region of treatment (municipality). Close variables are included in bins of 10km, so Close 1 refers to distances of [0,10)km, Close 2 refers to [10,20)km, and so forth. Models are estimated using a binary (logit) model for birth versus no birth. Coefficients are expressed as log odds.

Emergency Contraceptive Pill in Chile

The effect sizes are quite large. There are a few things to consider:

- Roe vs Wade in USA:
  - Bailey (2006) -0.093 (0.043)
  - Guldi (2008) -0.100 (0.054)
  - Ananat and Hungerman (2012) -0.043 (0.015)
- Contraceptive Pill in USA:
  - Bailey (2006) -0.074 (0.057)
  - Guldi (2008) -0.085 (0.041)
  - Ananat and Hungerman (2012) -0.088 (0.022)
- Morning after pill in USA:
  - Gross et al (2014) -0.020 (0.020)
- 16 and Pregnant in USA:
  - Kearney and Levine (2014) -0.057

Figure 4 : Placebo Test 1: Parallel Trends Between Treatment and Control

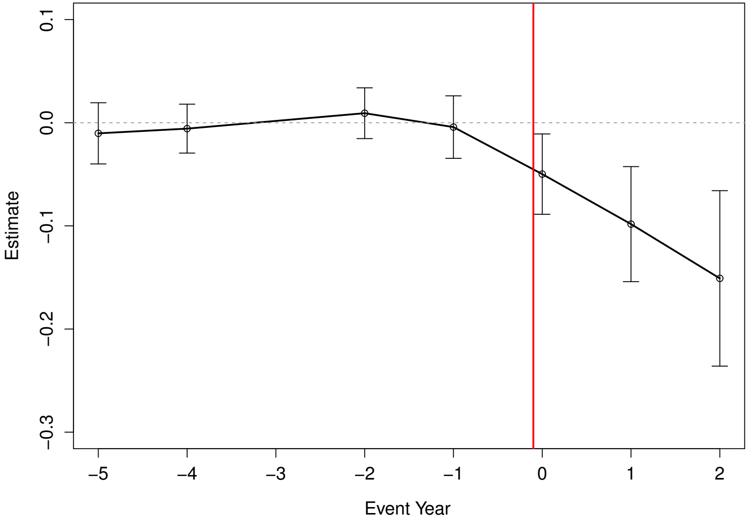
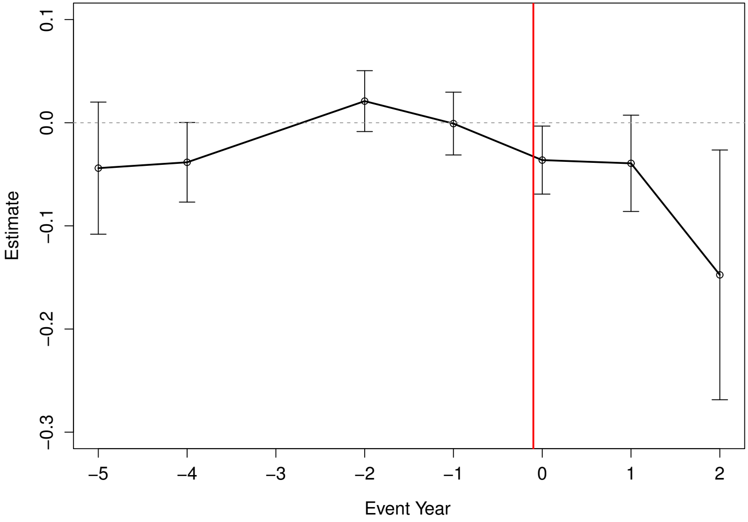


Figure 5 : Placebo Test 1: Parallel Trends Between Close and Control



Empirical Application 2: Legal Interuption of Pregnancy in Mexico DF

On April 26, 2007 the legislative assembly of Mexico DF voted to legalise legal interruption of pregnancy (ILE) whenever requested by the woman up to 12 weeks of gestation, reforming article 144 of the penal code of Mexico DF

- This made Mexico DF one of the most liberal areas in terms of abortion contraception in all of Latin America (Fraser, Lancet 2015)
- I collect data on births (INEGI), and municipio controls
- Further descriptive statistics.

Table 2 : Treatment Effects and Spillovers: Mexico (15-19 year olds)

	N Birth (1)	N Birth (2)	N Birth (3)	N Birth (4)	N Birth (5)
Treatment	-125.3***	-126.0***	-127.0***	-127.2***	-127.2***
	(45.33)	(45.36)	(45.33)	(45.32)	(45.32)
Close 1		-119.9**	-120.7**	-120.9**	-120.9**
		(52.69)	(52.87)	(52.88)	(52.88)
Close 2			-40.51**	-40.70**	-40.70**
			(19.92)	(19.92)	(19.92)
Close 3				-9.295	-9.296
				(15.62)	(15.62)
Close 4					-0.0524
					(13.95)
Mean	1,632	1,632	1,632	1,632	1,632
Regions×Time	24,550	24,550	24,550	24,550	24,550

NOTES: Each column represents a separate difference-in-differences regression including full time and municipal fixed effects and linear trends by municipality. Standard errors are clustered at the level of the geographic region of treatment (municipality). Close variables are included in bins of 10km, so Close 1 refers to distances of [0,10)km, Close 2 refers to [10,20)km, and so forth. The dependent variable is a count of all births in the municipality, and is estimated by OLS. Further details regarding controls can be found in the appendix.

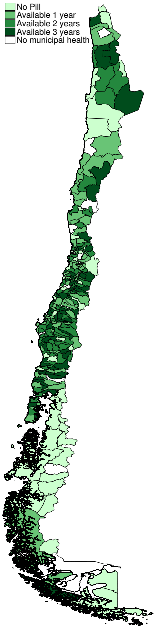
Contraceptive Reforms in Latin America

In each case, naïve diff-in-diff fails to capture spillovers to 'close' areas

- "Close" areas are affected similarly (though in lower magnitude) by these reforms
- In both cases, diffusion of the reform appears to last for 20-30 km
- In Chile, correcting for spillovers corrects for an attenuation bias
- In Mexico, while significant effects are felt in close areas, the correction for these does not significantly effect estimates of ATT
- This can be explained by the number of close municipalities…

Figure 6 : Mexico Reform Areas

Figure 7 : Chile Reform Areas



Robustness to Alternative Specifications

I have reported a small number of specification and definitions of "close"

- However, results are generally robust to alternative models and defintions
  - Estimating with comuna-level count data instead of an individual-level binary model
  - Defining point-to-point distance by travel over roads or travel time in vehicle
  - Further results and robustness tests presented in paper, and Bentancor and Clarke (2014)

Conclusion and Future Work

I introduce a flexible methodology to test for spillovers, and loosen the requirements of SUTVA in diff-in-diff studies

- Rather than imposing that each unit can affect no other units, identification relies on having units sufficiently 'far away' from the reform who are unaffected
- Here this is examined in terms of geographic distance, but this methodology can be arbitrarily applied to many structures: nodes in a network, ethnic distance, multidimensional measures...
- It is illustrated that this methodology can correct for attenuation in naïve diff-in-diff, as well as providing an alternative estimand of interest (ATC)

Conclusion and Future Work

- Current work extends to using a historical well documented contraceptive reform in USA
- Extension to a structural interpretation *a-la* Heckman & Vytlacil to motivate access to treatment
- Stata module `cdifdif` (and full source code and data) available for download at `github.com/damiancclarke/spillovers/`

Appendices

Table 3 : Summary Statistics

	No Pill Available	Pill Available	Total
MUNICIPALITY CHARACTERISTICS			
Poverty	16.4	17.0	16.6
	(7.47)	(7.56)	(7.49)
Conservative	0.286	0.267	0.281
	(0.452)	(0.443)	(0.45)
Education Spending	4,817	5,980	5,108
	(5,649)	(6,216)	(5,818)
Health Spending	1,866	2,788	2,096
	(2,635)	(3,381)	(2,867)
Out of School	4.07	3.98	4.05
	(3.16)	(3.06)	(3.13)
Female Mayor	0.120	0.134	0.123
	(0.325)	(0.341)	(0.329)
Female Poverty	60.5	62.0	60.8
	(10.64)	(9.48)	(10.4)
Pill Distance	5.94	0.00	4.46
	(18.4)	(0.0)	(16.1)
INDIVIDUAL CHARACTERISTICS			
Live Births	0.054	0.053	0.054
	(0.226)	(0.224)	(0.226)
Fetal Deaths	0.0558	0.0513	0.0547
	(0.269)	(0.256)	(0.266)
Birthweight	3322.7	3334.3	3324.7
	(540.0)	(542.3)	(540.4)
Maternal education	11.92	12.03	11.94
	(2.967)	(2.894)	(2.955)
Percent working	0.295	0.395	0.312
	(0.456)	(0.489)	(0.463)
Married	0.340	0.309	0.335
	(0.474)	(0.462)	(0.472)
Age at Birth	27.05	27.15	27.07
	(6.777)	(6.790)	(6.779)
N Comunas	346	280	346
N Fetal Deaths	9,999	3,064	13,063
N Births	1,214,088	391,212	1,605,300

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Table 4 : Descriptive Statistics (Mexico)

	Observations	Mean	Std. Dev.	Min.	Max.
Treatment	24550	0.00	0.04	0	1
Close to Treatment	24550	0.00	0.05	0	1
Number of Births (Mexico DF)	160	11744.75	8835.83	1550	34729
Number of Births (Close to DF)	250	12419.40	9254.72	1550	39745
Number of Births (Other Areas)	24300	785.99	3153.99	0	86659
Year (2001-2010)	24550	2005.50	2.87	2001	2010
Number of Medical Staff	24550	57.97	250.81	0	6212
Number of Classrooms	24550	303.51	1000.80	0	19280
Number of Libraries	24550	4.27	16.95	0	708
Municipal Income	24550	75.51	254.56	0	6615
Municipal Spending	24550	82.71	271.05	0	6615
Regional Unemployment Rate	24550	2.93	1.46	0	9

NOTES: Observations are for 2,455 municipalities in 10 years. Number of births refers to total counts for all women aged 15-49 in each municipality within the given area. Municipal income and municipal spending refer to tax receipts and outlays, and are expressed in millions of pesos.

Figure 8 : Birth Figures and ILE Use (Mexico)

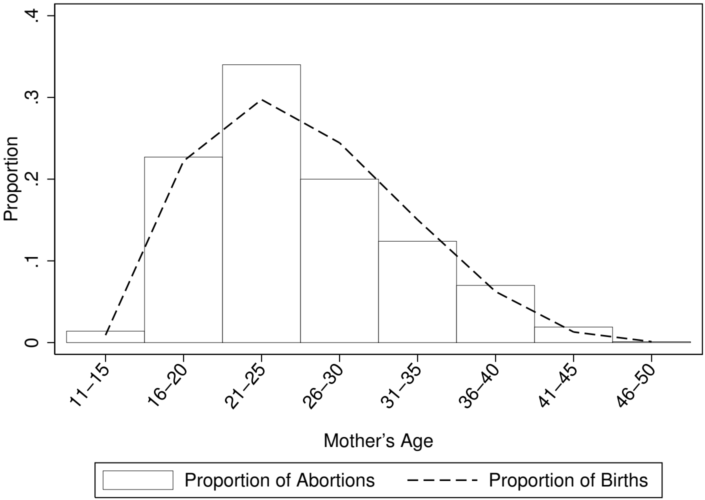

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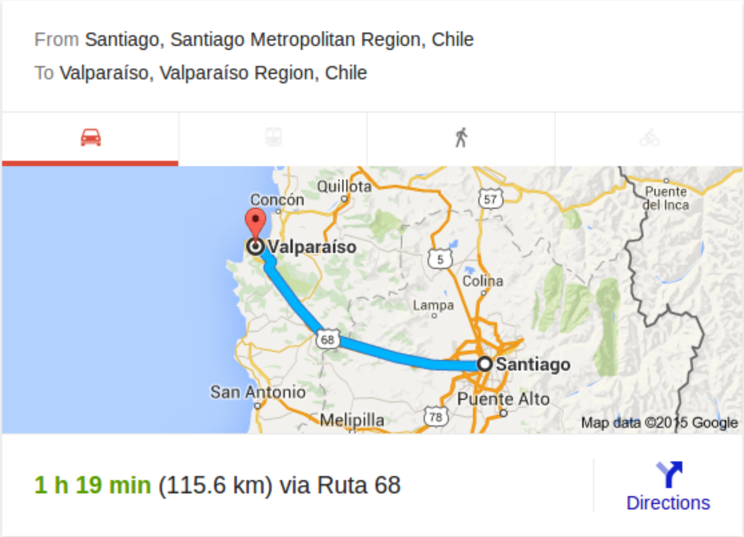
Figure 9 : Alternative Distance Measured from Repeated Calls to googlemaps



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Gross et al. (2014): EC in USA

"This paper studies the effect of EC during a time period in which abortion was legal. The effect of EC might be very different [were] abortion to be illegal (Bailey, Guldi, & Hershbein, 2013; Joyce, 2013)."

- Gross et al. explicitly consider the outside cost of abortion A
- One may hyptohesise that $A_{Chile} >> A_{USA}$
- From Gross et al. "These costs and benefits [A] reflect not only the financial cost of abortion or pregnancy, but also stigma, opportunity cost, and psychic costs."

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