Can growth take place while reducing emissions?

V Coloquio Nacional de Estudiantes Doctorales de Economía

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Agenda

Why should economists care about climate policy?

CO_2 emissions are closely related to economic growth. View

- Many countries have decoupled economic growth from CO_2 emissions, but others have not. View
- There are additional influences such as the energy matrix, that help to minimize the negative effects on economic growth. View

One of the most widely used climate policy tools is the carbon tax.

- 37 countries have implemented a carbon pricing policy, of which 28 are a carbon tax.
- The carbon tax creates incentives for countries to switch to less carbon- and energy-intensive forms of production.
- The carbon tax assigns a price to the tons of CO_2 emitted, which can vary from 2 usd/ton to 137 usd/ton. View

Does the effect of the carbon tax depend on the energy matrix?

This article addresses the following questions:

- Does the share of primary energy source influence the effect of the carbon tax on economic growth and employment?
- Under what combination of energy sources does the carbon tax favor economic growth?

How?

- Following the model of Acemoglu et al., (2012)[1]
  - Two substitute sectors clean and dirty,
  - model of directed technological change with environmental constraint,
  - considering the initial share of production using clean and dirty inputs,
  - two situations: autarky, with an optimal enviromental policies. .
- Empirical strategy: Study of Events, using different samples of countries according to the composition of the energy matrix.

[1] Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. 2012."The Environment and Directed Technical Change." American Economic Review, 102 (1): 131-66.

The energy matrix can intensify or attenuate the adverse effects of introducing a carbon tax

What do I find?

- With a cleaner energy matrix (low carbon), the carbon tax favors economic growth.
- A more carbon-intensive energy matrix, the carbon tax has a more negative effect on economic growth.
- With a more carbon-intensive energy matrix, implementing the tax slows economic growth in the short term, as they adapt new, less carbon-intensive technologies.

Contribution through the theoretical and empirical analysis of the macroeconomic effect of the carbon tax according to the primary sources of energy.

Environment and directed technological change. Acemoglu et al. (2012)

Model specifications

- A single final good, competitively produced using "clean" and "dirty" inputs, Y_{ct} and Y_{dt}:

$$Y_t = \left((Y_{ct})^{\frac{\epsilon-1}{\epsilon}} + (Y_{dt})^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{1}$$

  - The elasticity of substitution between the two sectors $\varepsilon > 1 \rightarrow$ the two sectors are substitutes.

- Environmental quality $S_t \in [0, \bar{S}]$, is depleted by production of a dirty input and partly regenerates.

$$S_{t+1} = -\xi Y_{dt} + (1+\rho) S_t \tag{2}$$

- $\xi > 0$ is the pollution rate and $\rho > 0$ the regeneration rate.
- Two situations:
  - Equilibrium *laissez faire* in autarky.
  - Tax on dirty production/subsidy for clean research.

Solving for the Laissez-Faire Equilibrium

- There are three forces that determine the relative growth of innovations and the relative benefits of innovating in the clean sector Π_{ct}, relative to the dirty sector Π_{dt}:

$$\frac{\Pi_{ct}}{\Pi_{dt}} = \left(\frac{p_{ct}}{p_{dt}}\right)^{\frac{1}{1-\alpha}} \times \frac{L_{ct}}{L_{dt}} \times \frac{A_{ct-1}}{A_{dt-1}} \tag{3}$$

  - Price effect: the less advanced sector is more expensive, which increases the incentive to innovate;
  - Scale effect: the most advanced sector has a larger market size, which increases the incentive to innovate;
  - Direct effect of productivity: the most advanced sector obtains greater benefits, which increases the incentive to innovate.

- In equilibrium, innovation occurs only in the dirty sector, which is initially more advanced.
  - This increases the gap between the dirty and clean sectors.
  - The economy hits an environmental disaster with S = 0 in finite time.

Solving with an optimal enviromental policies.

- Sustainable growth can be achieved with taxes and/or subsidies (τ_t, $q_t = \lambda\tau_t$) that *direct technological change* towards the clean sector.
- The tax that makes the probability of innovating in the clean sector higher than in the dirty sector is:

$$\frac{1-\lambda\tau_t}{1+\tau_t} > \left(\frac{A_{ct}}{A_{dt}}\right)^{\frac{(1-\alpha)(\epsilon-1)-1}{\epsilon}} \tag{4}$$

- Where $\frac{Y_{jt}}{Y}$ is the initial production of each sector.
- The growth rate of aggregate productivity $g_t = \frac{\Delta Y}{Y}$ is:

$$g_t = \frac{\Delta Y_t}{Y} = \left(\frac{Y_{ct}}{Y}^{\frac{\epsilon-1}{\epsilon}}(P_{ct}(1-\lambda\tau_t))^{\frac{1}{1-\alpha}} + \frac{Y_{dt}}{Y}^{\frac{\epsilon-1}{\epsilon}}(P_{dt}(1+\tau_t)^{\frac{1}{1-\alpha}}\right)\cdot\alpha(1-\alpha)(\gamma-1) \tag{5}$$

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Proposición 1: *El efecto de introducir un impuesto al carbono τ_t y un subsidio a las energías limpias sobre la tasa de crecimiento del PIB, g_t, es una función creciente de la participación del sector limpio.* Ejemplo

Optimal Policy

- Environmental policies such as a carbon tax on dirty production (τ_t) or a subsidy in the clean sector (q_t) can redirect innovations to the clean sector.[2]

Proposition

The effect of introducing a carbon tax on the GDP growth rate g_t, is an increasing function of the initial share of clean sector in the production. The greater the initial participation of the clean sector in the final product, the greater the positive effect of carbon tax on growth rate. Proof

Implications

- *Corolario 1: if* $\frac{Y_{ct}}{Y} > mean \Longrightarrow$ ***positive effect,***
- *Corolario 2: if* $\frac{Y_{ct}}{Y} < mean \Longrightarrow$ ***negative effect,***
- *Corolario 3: if* $\frac{Y_{ct}}{Y} \gg \frac{Y_{ct}}{Y} \Longrightarrow$ $\downarrow$***negative effect,*** $\uparrow$***positive effect.***

[2]Research subsidies correct building on the shoulders of giants externality and the knowledge externality.

From theoretical to empirical

Theoretical Prediction: Effect of the carbon tax on the growth rate.

$$\frac{\partial g_t}{\partial \tau_t} = \left(\frac{Y_{ct}}{Y}^{\frac{\epsilon-1}{\epsilon}} (P_{ct}(1-\lambda\tau_t))^{\frac{\alpha}{1-\alpha}} + \frac{Y_{dt}}{Y}^{\frac{\epsilon-1}{\epsilon}} (P_{dt}(1+\tau_t)^{\frac{\alpha}{1-\alpha}} \right) \cdot \frac{\alpha(\gamma-1)}{(1-\alpha)} \tag{6}$$

Empirical counterpart:

$$GDP_{c,t} = \sum_{r=-S}^{-1} \beta_r \cdot D^r_{c,t} + \sum_{r=1}^{M} \beta_r \cdot D^r_{c,t} + \gamma_c + \Phi_t + \varepsilon_{c,t} \tag{7}$$

- $GDP_{c,t} \equiv \frac{\partial g_t}{\partial \tau_t}$ is the annual GDP growth rate in country c, in year t.
- $D^r_{c,t} \equiv \tau_t$ 1 if year t is r periods from the year of implementation of carbon tax.
- β_r the acumulative effect on the GDP growth relative to the year of implementation.
- γ_c country fixed effects c
- Φ_t time fixed effects.

Two samples:

- Clean countries: $\frac{Low-carbonenergy}{Totalenergy} > mean \equiv \frac{Y_{ct}}{Y}$.
- Dirty countries: $\frac{High-carbonenergy}{Totalenergy} < mean \equiv \frac{Y_{dt}}{Y}$.

Data

- *Carbon Pricing Dashboard* Variables on carbon pricing initiatives in the world, 1990-2022.
- *WorldBank Data and Penn World Table* Macroeconomics variables, 1990-2020.
- *Our World in Data* Variables of energy, 1990 -2021.

Cuadro: Description of the main outcome variables.

Variable	**Mean**	**Median**	**Std. Dev.**	**Source**
Real GDP at constant domestic prices (millions 2017US$)	1026887	258975	2511953	Penn World Table
Crecimiento del PIB (anual %)	2.86 %	2.99 %	4.33 %	Data WorldBank
GDP per capita (current US$)	9.384	9.532	1.143	Data WorldBank
Employment rate (% total labor)	92.30 %	92.94 %	4.56 %	Data WorldBank
Population, total	49035868	9771437	165987702	Data WorldBank
Primary energy consumption (TWh)	1589	324	4390	Our World in Data.
Clean energy fraction* (% total consumption)	14 %	9 %	16 %	Our World in Data.
Clean electricity fraction* (% total consumption)	37 %	32 %	31 %	Our World in Data.
Countries	74			
Observations	2511			

**Primary sources of clean energy are hydro, nuclear, solar and wind power.*

Sample balance

Effect of carbon tax on growth rate and employment

Full sample

Figura: GDP growth (% annual)

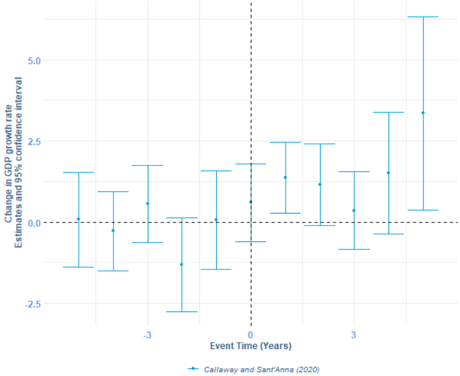
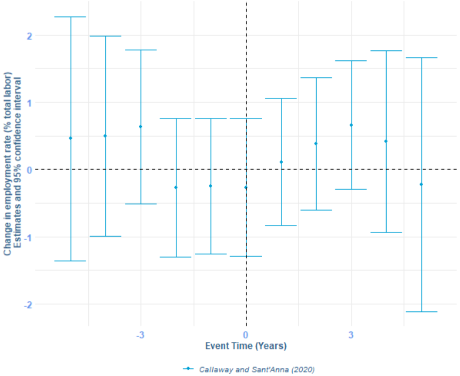


Figura: Employment rate (% total labor)



- ↑ GDP growth rate 1.3 percentage points at t=1.
- ↑ employment rate 0.66 percentage points at t=3. Not statistically significant.

Effect of carbon tax on growth rate

Countries with dirty energy sources.

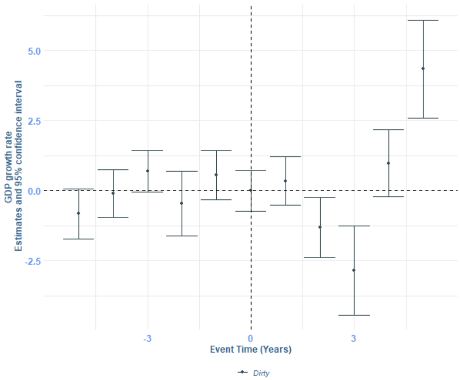


Figura: GDP growth (% annual)

Countries with clean energy sources.

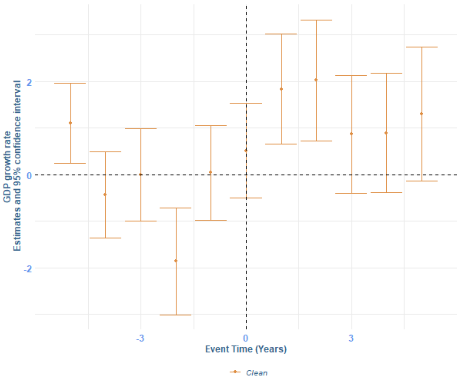


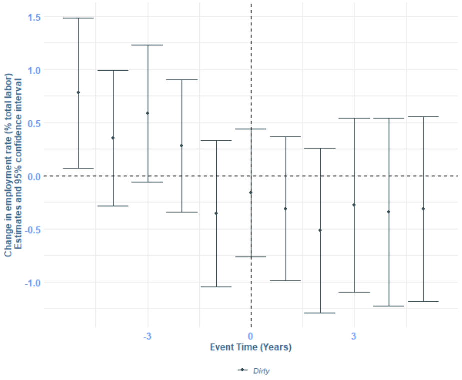
Figura: Crecimiento del PIB (% anual)

- ↓ GDP growth rate. (-1.3 percentage points at t=2 and -2.8 percentage points at t=3) in countries with dirty energy sources.
- ↑ GDP growth rate at 1.8 percentage points at t=1 in countries with clean energy sources.

Effect of carbon tax on employment rate

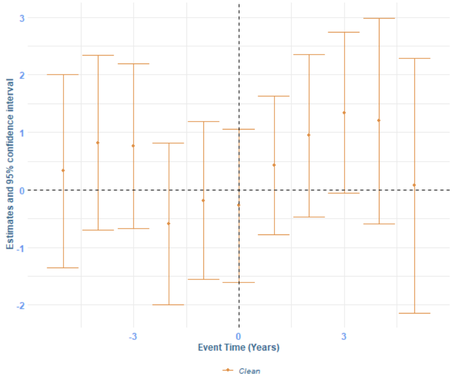
Countries with dirty energy sources.

Figura: Employment rate (% total labor)



Countries with clean energy sources.

Figura: Employment rate (% total labor)



- ↓ employment rate (-0.3 percentage points at t=1 and -0.5 percentage points at t=2) in countries with dirty energy sources.
- ↑ employment rate at 0.4 percentage points at t = 1 and 1 percentage points at t=2 in countries with clean energy sources.

Effect with different shares of clean energy.

Change in GDP growth

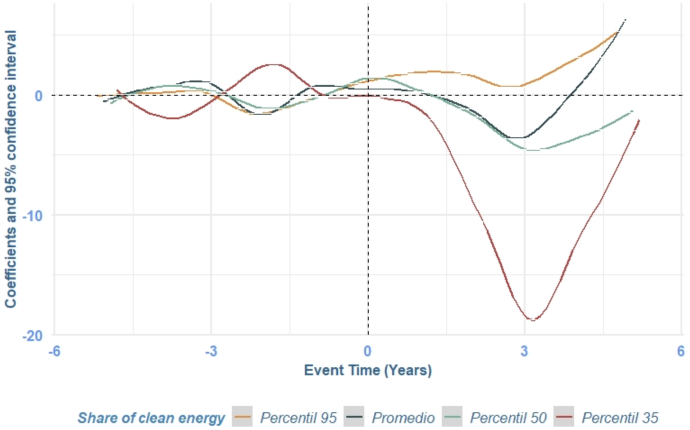
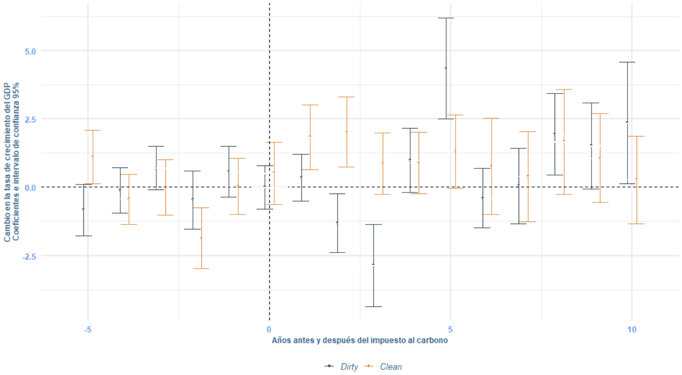


Figura: Effect of the carbon tax at different share of clean energy.

Long run effect of carbon tax on growth rate

Change of GDP growth in long run

Figura: GDP growth (% annual)



Countries with a higher than average share of energy from dirty sources have initially a negative effect on the growth rate. This effect dissipates in the long run. *Corollary 3*

Conclusions

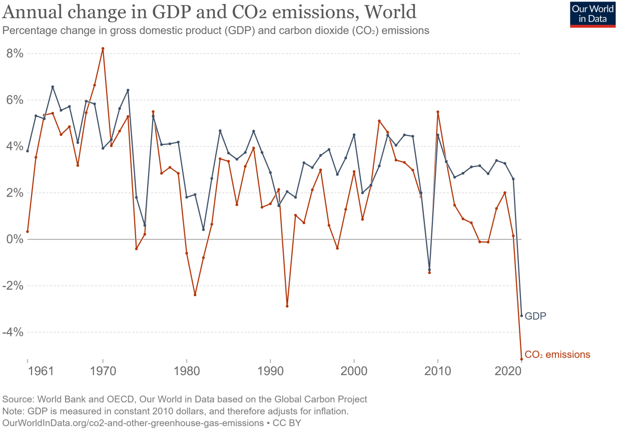
- In the absence of subsidies, carbon taxes have a negative effect of economic growth.
- The effect of carbon tax on economic growth is a increasing function of the share of clean goods in total output.
- The greater the share of clean energy in production, the greater the positive effect of a carbon tax on economic growth.

Primary energy sources can enhance or attenuate the adverse effects of introducing a carbon tax on economic growth.

- Energy matrix composed of low-carbon sources $\Longrightarrow$ positive effect on economic growth.
- Energy matrix composed of high-carbon sources $\Longrightarrow$ negative effect on economic growth.

CO2 emissions and GDP

Annual change in GDP and CO2 emissions, World.



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CO2 emissions and GDP

Many countries have decoupled economic growth from CO emissions

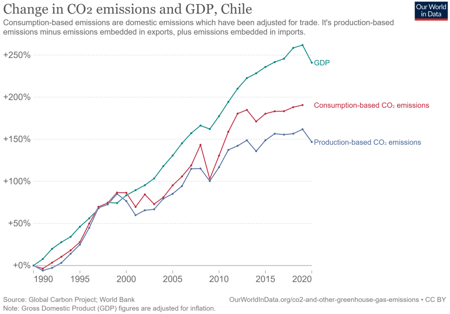

Figura: Change in CO2 emissions and GDP, Chile.

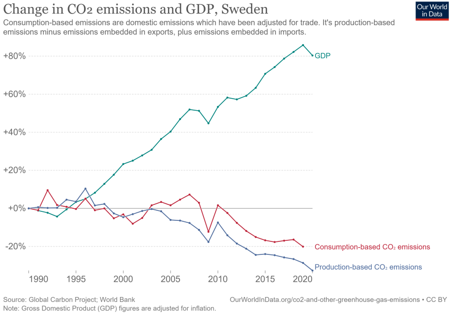

Figura: Change in CO2 emissions and GDP, Sweden.

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What are the drivers that determines the CO2 emissions?

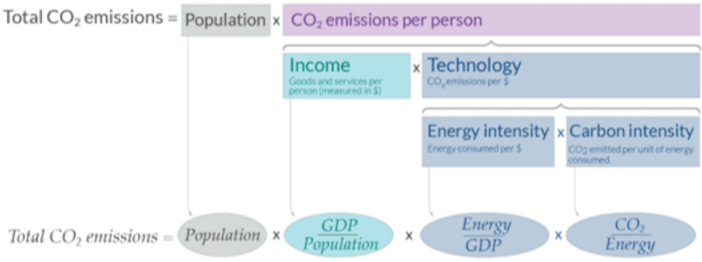

Figura: Drivers of CO2 emissions.

- ↓ energy intensity through: improving energy efficiency and/or switching to less intensive industries.
- ↓ carbon intensity through: shift to renewable energy, shift to nuclear power, fossil CO2 capture and storage (CCS).

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Summary map of national carbon tax.

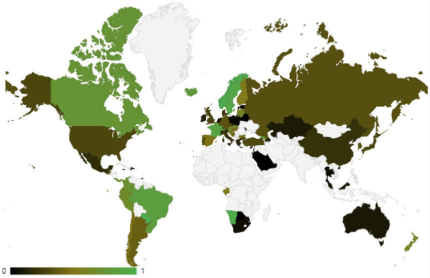

Figura: Map of countries according to primary energy share

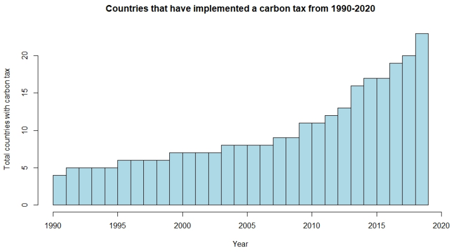

Figura: Number of countries that have implemented a carbon tax in recent years.

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Proof of Proposition

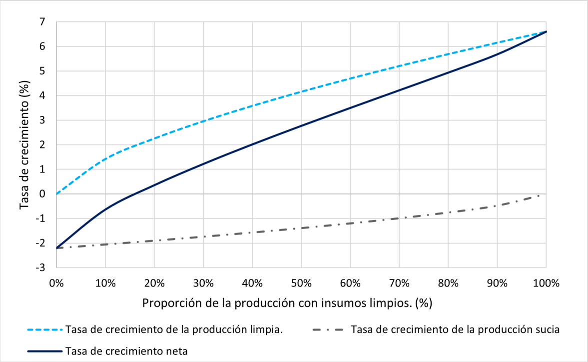

Figura: Representación del cambio en la tasa de crecimiento dada la existencia de un impuesto al carbono, (g_t/τ), según la proporción de la producción final producida con insumos limpios, λ_t.

Nota: Calibrado con los siguientes valores: $\alpha = 0{,}5$, $\epsilon = 3$, $\tau = 2$

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Anexo: Sampling balance

Cuadro: Sampling balance

Variable	Media	Mediana	Desv. Estándar	Media	Mediana	Desv. Estándar
			Panel todos los datos			
	Con impuesto al carbono			Sin impuesto al carbono		
PIB real (millions 2017US$)	850686.90	393482.88	1082446.42	1121275.39	166135.61	3006622.00
PIB per cápita (current US$)	9.89 %	10.10 %	0.94 %	9.11 %	9.15 %	1.15 %
Crecimiento del PIB (anual %)	2.482	2.683	3.694	3.058	3.254	4.630
Tasa de empleo (% total labor)	92.07 %	92.85 %	4.75 %	92.43 %	93.02 %	4.45 %
Consumo de energía primaria (TWh)	1094.63	474.96	1379.31	1855.63	254.93	5334.58
Fracción de electricidad limpia (% total consumo)	47 %	46 %	33 %	31 %	24 %	29 %
Fracción de energía limpia (% total consumo)	23 %	18 %	20 %	9 %	4 %	11 %
Países	23			51		
			Panel - Países con matriz energética relativamente 'limpia'			
	Con impuesto al carbono			Sin impuesto al carbono		
PIB real (millions 2017US$)	609238.88	322000.91	721705.56	654034.94	161623.54	1096710.94
Crecimiento del PIB (anual %)	10.02 %	10.17 %	0.91 %	9.26 %	9.44 %	1.04 %
PIB per cápita (current US$)	2.17	2.57	3.28	2.35	2.67	3.47
Tasa de empleo (% total labor)	92.14 %	92.70 %	4.51 %	90.99 %	91.68 %	4.23 %
Consumo de energía primaria (TWh)	841.80	351.14	1103.98	748.81	232.82	1166.34
Fracción de energía limpia (% total consumo)	70 %	71 %	21 %	60 %	60 %	16 %
Fracción de electricidad limpia (% total consumo)	36 %	32 %	17 %	23 %	23 %	8 %
Países	13			12		
			Panel - Países con matriz energética relativamente 'sucia'			
	Con impuesto al carbono			Sin impuesto al carbono		
PIB real (millions 2017US$)	1164569.32	579572.91	1359162.31	1302519.86	168376.80	3459270.47
Crecimiento del PIB (anual %)	9.72 %	9.86 %	0.95 %	9.06 %	9.07 %	1.19 %
PIB per cápita (current US$)	2.89	2.83	4.14	3.33	3.57	4.98
Tasa de empleo (% total labor)	91.97 %	93.96 %	5.06 %	93.06 %	93.67 %	4.39 %
Consumo de energía primaria (TWh)	1423.29	1010.65	1614.45	2289.49	277.86	6198.64
Fracción de energía limpia (% total consumo)	16 %	12 %	15 %	19 %	10 %	24 %
Fracción de electricidad limpia (% total consumo)	6 %	5 %	6 %	3 %	1 %	5 %
Países	10			49		

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