Subway Systems and Attractiveness of Cities for FDI

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Introduction

Metro systems are increasingly important around the world:

- 137 cities had a metro system in 2003
- 50 cities build a new metro system between 2013 and 2015
- 35 metro systems are currently under construction

In addition, existing metro have grown over the considered period (2003-2015):

- 10% growth for metro initially build before 1960
- 29% growth for those build over the period 1960-1980
- Over 100% growth for metro build over the period 1980-2002

Despite this increasing importance, very few paper look at their economic consequences
Aim of the paper
Does the presence (or the development) of a metro system have an impact on the Foreign Direct Investments (FDI) at the city level?

Contributions
- Creation of a new database at the city level combining informations on metro systems, FDI and many control variables
- The database if used to study
  - The extensive margin: the effect of the presence of a metro
  - The intensive margin: the effect of the size of the system
In cross-section, we find a positive effect of the presence of a metro on the number of FDI at both, the intensive and the extensive margin.

When instrumenting, it appears that the main driver of the evolution of FDI is the growth of the metro system.

Results appear to be sensitive to geographical situation of cities (at the continental level) and the nature of FDIs.
THE DATA
The database

We combined many different data sources that have been geolocalized at the city level.

There are 4 main categories detailed below:

- Base of the urban areas (defined by the observed urban sprawl rather than by the administrative borders)
- FDI database
- Metro infrastructure database
- Control variables (from various sources).
Urban areas

Goal: identify a world list of urban areas with a spatial definition of their borders

**MODIS 500** (Schneider, 2009) which is the most reliable to define the urbanized areas

- Obtained from satellite pictures at a resolution of 500 meters to assess the building of the planet in the year 2000, we obtain **3 729 urban areas**.
- These urban areas are used to define and match all our data in our estimations

The **UN population data** provides population data for cities bigger than 300,000 inhabitants since 1950 and with forecasts up to 2030

- We end up with **1,602 urban areas**

<table>
<thead>
<tr>
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<th>Mean</th>
<th>Standard deviation</th>
<th>Median</th>
<th>Total</th>
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<tbody>
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<td>1,369,819</td>
<td>212,640</td>
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<tr>
<td>Area in km²</td>
<td>90,4</td>
<td>252,7</td>
<td>33,66</td>
<td>337,119</td>
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</table>

**Table**: Descriptive statistics of urban areas
**Figure:** Urban areas in Europe
We use three alternative definitions of the urban area to perform sensitivity analysis: the urban areas defined by MODIS 500 and the urban area increased with buffers at 2 km and 5 km
fDiMarkets reports every greenfield Foreign Direct Investment project performed by multinational companies from 2003 to 2014.

For each project, we have:

- The name of the company
- The home country of the company
- The sector of activity of the investment
- The location of the investment in the receiving country at the city level

Every project has been geolocalized.

A project is considered to be located in a city if it belongs to the urban area increased with a buffer of 5 km.

We have 112,190 observations over the period. We use the number of greenfield FDI projects in a city as our main dependent variable.
**Figure**: Annual number of FDI

![Graph showing the annual number of FDI projects from 2003 to 2013.](image)

- The graph plots the number of FDI projects (N. Projets) on the Y-axis and the years (2003 to 2013) on the X-axis.
- The number of projects ranges from 8000 to 16000.
- There are peaks in 2005, 2007, and 2011, with a significant increase from 2003 to 2005 and a decline after 2009.
- The data represents trends in foreign direct investment projects.
**Figure:** Location of FDI in Paris
**Figure:** Number of FDI per city
Metro database

Building of a new database of the metro systems

First issue: the characteristics of a metro system

- The lane cannot be shared with other transport modes
- High frequency
- Stations must be spatially close to each other

After careful verification, we obtain two databases

- A large database containing exotic systems
- A small database with metro corresponding to strict definition

For every system from every city, we collected information regarding the year of commissioning of the metro system and the size of the system for each year from the creation

This variable is our variable of interest
**Figure:** Metro cities in the world
# Descriptive statistics for metro systems

The following table provides descriptive statistics for metro systems:

<table>
<thead>
<tr>
<th></th>
<th>Length (km)</th>
<th>N. Lines</th>
<th>N. Stations</th>
<th>Age</th>
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<tbody>
<tr>
<td>Nombre</td>
<td>67.91</td>
<td>3.5</td>
<td>58.05</td>
<td>34.35</td>
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<tr>
<td>Mean</td>
<td>92.91</td>
<td>3.89</td>
<td>75.34</td>
<td>31.02</td>
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<td>St. dev.</td>
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<td>2</td>
<td>31</td>
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<tr>
<td>Total</td>
<td>12700</td>
<td>654</td>
<td>10855</td>
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</table>

**Table**: Descriptive statistics for metro systems

- **34 systems under construction** (not yet in operation in 2015)
- 33 in Asia and Middle-East
- 1 in Europe
Figure: Total length of metro lines since 1950
**Figure**: City ranking by FDI and metro systems
Other transport infrastructures

**VMAP** is managed by the US government

- Roads
- Railways
- Airport

**World Port Index.**

**OpenStreet** for intra-urban roads and alternative measure of metro systems (imprecise)
Lights at night are used as proxies for urban GDP

**NOAA** provides two measures of lights at night:

- **saturated lights** are measured on a scale going from 0 to an upper bound of 63. These data are available every year from 1992 to 2013.

Radiance lights are used for cross-section regressions and saturated lights for panel estimations.
**Figure**: Urban GDP for *OCDE* cities and lights at night
**G-Econ** is a geophysically based data set on economic activity for the world.

These data are used to control for:
- Land elevation
- Roughness of the territory,
- Distances to ocean and main waterways
- Weather variables

There are 27,000 cells of 1 degree of longitude and 1 degree of latitude (corresponding to a square of 100 km on 100 km at equator).

We weight values for our cities according to the proportion of the cells covered by the urban area.
CROSS-SECTION APPROACH
In this section, the dependent variable is the total number of greenfield FDI between 2003 and 2014.

We use a Poisson model to account from the fact that the dependent variable is a count variable.

In the absence of fixed effects, we use the country GDP provided by the Penn World Table together with the country ranking of the Ease of doing business of the World Bank.

The extensive margin if captured by a dummy variable equal to one if there was a metro before 2003 and another dummy variable if a metro was build over the period.

The intensive margin is measured by $\ln(m_i + 1)$ where $m_i$ is the length of the metro in 2003 and a measure of the growth of the metro over the period.

We use the log of the continuous control variable,
**Table: Poisson - extensive margin**

<table>
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<tr>
<th></th>
<th>(1) Poisson</th>
<th>(2) Poisson</th>
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<th>(4) Poisson</th>
<th>(5) Pois. FE-pays</th>
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<td>Ind. métro avant 03</td>
<td>0.946***</td>
<td>0.910***</td>
<td>0.774***</td>
<td>0.581***</td>
<td>0.505***</td>
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<td></td>
<td>(0.272)</td>
<td>(0.233)</td>
<td>(0.244)</td>
<td>(0.199)</td>
<td>(0.164)</td>
</tr>
<tr>
<td>Ind. métro après 02</td>
<td>0.831***</td>
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<td>0.410***</td>
<td>0.472***</td>
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* p < 0.1, ** p < 0.05, *** p < 0.01. Écarts-types entre parenthèses par grappe par pays.
<table>
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<th>(6) Pois. FE-pays</th>
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<td>Taille métro 03</td>
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<td>0.206***</td>
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<td>0.609***</td>
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</table>

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Écarts-types entre parenthèses par grappe par pays.
Results summary

Extensive margin

- The presence of a metro system is associated to an average increase in the number of $FDI$ of $\exp(0.505 - 1) = 65\%$
- Control variables significantly reduce the estimated impact of the metro
- Results are consistent with linear or Poisson models

Intensive margin

- An increase of 10 % of the metro size in 2013 is associated to an increase of 1.4 % of the number of $FDI$.
- An increase of 10 % of the metro growth between 2003 and 2014 is associated to an increase of 0.2 % of the number of $FDI$. 
INSTRUMENTAL VARIABLES
Instrumental Variables

Three types of instruments have been tested:

- The lagged growth of population and metro systems
- Natural instruments such as nature of soils, land elevation, etc.
- Instruments obtained from the heteroskedasticity of the model (Lewbel, 2002).

Only the Lewbel method produces "good" instruments.

It appears that metro have been built whatever the soil composition or the land elevation.

Intuition of Lewbel’s instruments: Heteroskedasticity is obtained from unobserved factors uncorrelated with the error term. Therefore, the higher the heteroskedasticity, the more efficient the instruments.

In the next table, we instrument

- metro growth between 2003 and 2015
<table>
<thead>
<tr>
<th></th>
<th>(1) 2SLSH</th>
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<td>C. métro 03-14</td>
<td>0.0817***</td>
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<td>Var. démo. &amp; éco</td>
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<td>Oui</td>
<td>Oui</td>
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</table>

F statistic for weak identification (Cragg-Donald or Kleibergen-Paap).

(1) Instrumented variable : metro growth and tramway.
(2) Instrumented variable : (1) and population in 2003.
(3) Instrumented variable : (2) and new metro.
(4) Instrumented variable : (3) large metro base.
(5) Instrumented variable : (3) small metro base.
PANEL MODEL : TBC
Panel model

For the panel estimation with city fixed effect, we have the following variables

- Number of *FDI* projects
- Metro size
- Population
- Light at night
- Country GDP

We also test a dummy equal to one if a metro appears in the city

We add continental and year dummies

*FDI* are aggregated over two years to reduce noise
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Table: Panel model with city fixed effects for 2004-2009

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Preliminary conclusions

There exists a causal link between the presence of a metro system and the attractiveness of a city for FDI in the long run.

The causal link is more difficult to identify in the short run.

Various heterogeneity sources must be analyzed:

- Temporal disparities (before vs. after the crisis)
- Geographical disparities (by continent)
- Nature of FDI (headquarters, labor intensive activities, etc.)
HETEROGENEITY
Heterogeneity

Results by continent

- Europe vs. Asia

Results by activity

- Headquarters
- labor intensive activities (TBD)
APPENDIX 1 : LINEAR (BASELINE) MODEL
### Table: Linear model : extensive margin

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* p < 0.1, ** p < 0.05, *** p < 0.01. Écart-types entre parenthèses par grappe par pays.
### Table: Linear model: intensive margin

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* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Écarts-types entre parenthèses par grappe par pays.
### Table: Robustness tests: extensive and intensive margins

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APPENDIX 2 : IMPACT OF TRAMWAY
**Table:** Variables instrumentales générées uniquement sans tramway

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F statistic for weak identification (Cragg-Donald or Kleibergen-Paap).

(1) variables instrumentées : croissance du métro.
(2) variables instrumentées : (1) plus la taille de la population en 2003.
(3) variables instrumentées : (2) plus la taille des nouveaux métros.
(4) variables instrumentées : (3) base métro large.
(5) variables instrumentées : (3) base métro restreinte.
Table: Variables instrumentales retardées et générées

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F statistic for weak identification (Cragg-Donald or Kleibergen-Paap)

Bono; David; Desbordes; Py - FDI et métro

Dec. 2016 - 44 / 63
**Table: Autres variables dépendantes**

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APPENDIX 3 : RESULTS BY CONTINENT
### Table: Poisson model by continent

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Bono; David; Desbordes; Py - FDI et métro  
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APPENDIX 4 : RESULTS BY ACTIVITY
### Table: Distribution des FDI par activité

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* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Écart-types entre parenthèses par grappe par pays.
**Table: Activité FDI : quartier général**

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|                   |              |             |             |                  |           |
| Géographie         | Oui          | Oui         | Oui         | Oui              | Oui       |
|                   |              |             |             |                  |           |
| Météo             | Oui          | Oui         | Oui         | Oui              | Oui       |
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Observations 1574 1599 1574 1518 1574

$R^2$ 0.839 0.711 0.778 0.736
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**Table:** Activité FDI : R&D, design et éducation

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ANNEXE 5 : GRAPHIQUES SUPPLÉMENTAIRES
Figure: Les routes principales et FDI
**Figure:** Les routes principales et FDI
**Figure:** La grille surfacique *G-ECON*
**Figure:** Évolution par âge du métro

- Après 2002
- 1981-2002
- 1961-1980
- avant 1961
Figure: Évolution des 10 premières villes en termes de FDI
Figure: Age du métro, taille et nombre de passagers