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Centre International de Recherche sur l'Environnement et le Développement

Anticipating transit-induced changes in social composition of neighborhoods

an application to the Grand Paris Express

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Changes in socio-economic groups spatial repartition

Have high impacts on real estate prices and economic activity

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Have high impacts on city identity and social issues

How does public transit affect income sorting?

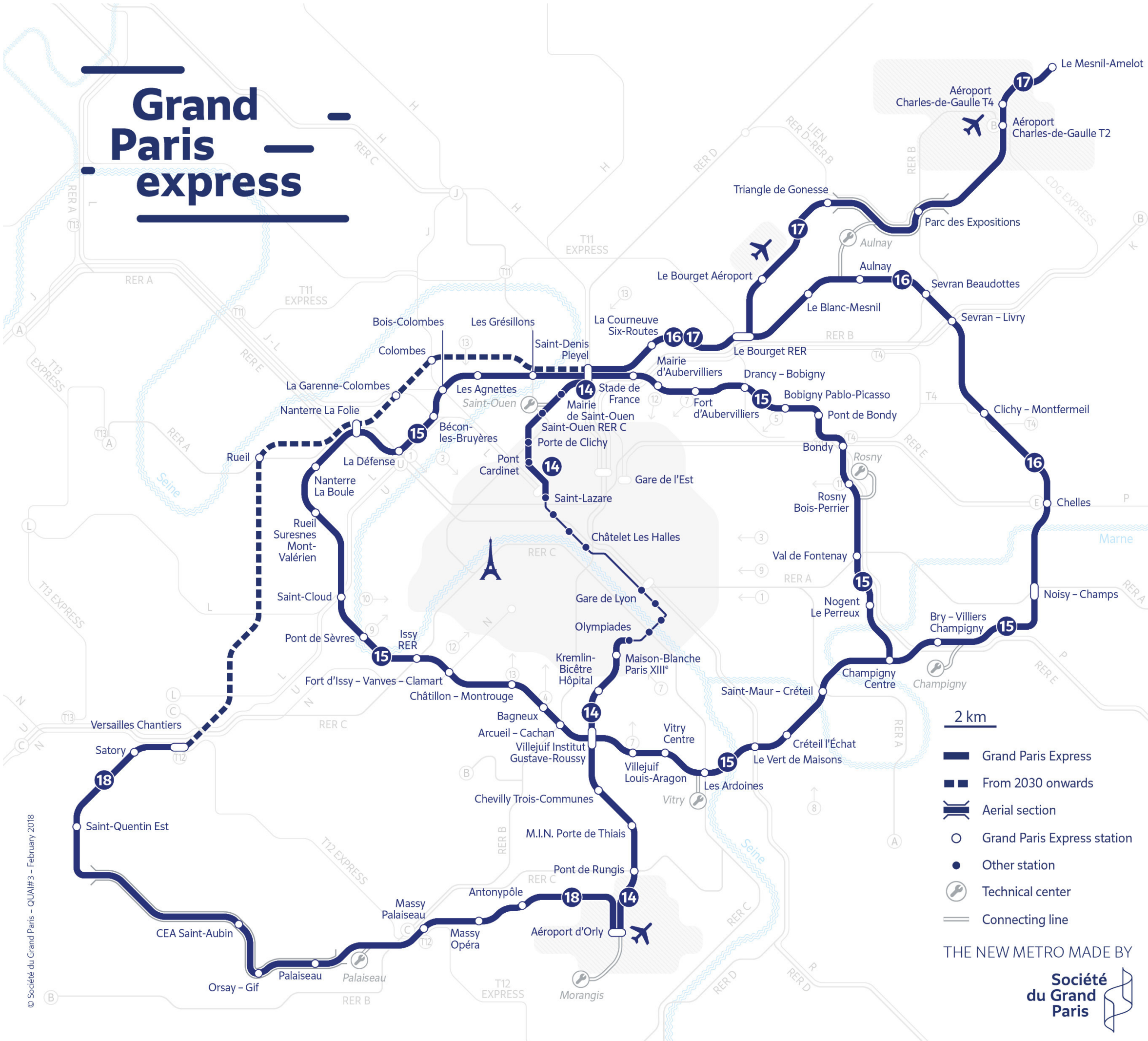
- **Transit infrastructures represent large public investments**
  - Anticipate their effects is needed to build efficient ones.
  - Whether a new public transit will generate gentrification may be important to determine its distributional effects.

- **The effects of public transit on income sorting are unclear**
  - Glaeser et al (2008) argue that public transportation explains central city poverty in US cities (see also Pathak et al, 2017).
  - Case studies find that public transit raised prices and increased local income (Bardaka et al., 2018) or share of educated workers (Mayer & Trevien, 2017).
  - Kahn (2007) finds heterogeneous effects depending on the type of stations ; Grube-Carbers & Patterson (2015) depending on the city.

- **Can we say better than 'it depends'?**

- **Recently, many empirical works using complex structural models**
  - Fretzet al. 2020. (Switzerland), Gaigne, et al. 2020. (Netherlands), Herzog 2020 (UK), Tsivanidis. 2019. (Colombia), Warnes. 2020. (Argentina)…

The Grand Paris Express project



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In this study

- **We develop a simple model**
  - Residence location is mainly driven by accessibility to jobs.
  - Job locations differ across income groups.
  - A new transit line that increases accessibility to high-income jobs **more** than to low-income jobs fosters gentrification.
- **We test this model on past data for the Paris region.**
- **We use the model to anticipate the impacts of the Grand Paris Express.**

THE MODEL

The model

- **Utility function for a worker of group *g* that live in neighborhood *i***

$$u_{ig} = z_{ig}^{\alpha} q_{ig}^{\beta} a_{ig}^{\gamma} b_{ig}^{\delta}$$

  - Composite good: Z_{ig}
  - Housing consumption: q_{ig}
  - Accessibility to group-*g* jobs: a_{ig}
  - Local amenities : b_{ig}

- **Budget constraint:** $w_g = z_{ig} + q_{ig}\psi_{ig}$

➔ **Bid-rent is:** $\psi_{ig} = \left[\alpha^{\alpha}\beta^{\beta}\frac{w_g}{u_g}\right]^{\frac{1}{\beta}} a_{ig}^{\frac{\gamma}{\beta}} b_{ig}^{\frac{\delta}{\beta}}$

The model (2) : Stochastic bid-price approach

- **A landlord *l* in location *i* renting out to a household from group *g* perceives a log-utility**

$$\log\left(\psi_{ig}\right) + \epsilon_l$$

where the ϵ_l follow a Gumbel-max law of parameter $1/\mu$.

(encompasses imperfect information, historical inertia or idiosyncratic preferences)

➔ Share of the floorspace in i that is allocated to workers of group g:

$$\sigma_{ig} = \frac{\left(\psi_{ig}\right)^{\mu}}{\sum_{h=1}^{G}\left(\psi_{ih}\right)^{\mu}} S_i$$

➔ Share of workers in i that belong to group g :

$$n_{ig} = \sigma_{ig}/q_{ig} = \frac{\left(\psi_{ig}\right)^{\mu+1}}{\sum_{h=1}^{G}\left(\psi_{ih}\right)^{\mu}} \frac{S_i}{\beta w_g}$$

Impact of a new transport infrastructure

- **superscript P = variable in the equilibrium situation with a new transport project built, all else being equal**

$$\frac{n_{ig}^P}{n_{ig}} = \left(\frac{a_{ig}^P}{a_{ig}}\right)^{\frac{\gamma}{\beta}(1+\mu)} \left(\frac{u_g^P}{u_g}\right)^{-\frac{(1+\mu)}{\beta}} \left(\frac{\sum_h (\psi_{ih}^P)^\mu}{\sum_h (\psi_{ih})^\mu}\right)^{-1}$$

So :

$$\log \frac{n_{ig}^P}{n_{ig}} = \overbrace{\frac{\gamma(1+\mu)}{\beta} \log\left(\frac{a_{ig}^P}{a_{ig}}\right)}^{\text{(i) group-location-specific increase in accessibility}} - \overbrace{\frac{(1+\mu)}{\beta} \log\left(\frac{u_g^P}{u_g}\right)}^{\text{(ii) group-specific equilibrium effect (closed city only)}} \underbrace{- \log\left(\frac{\sum_h \left(\frac{a_{ih}^P}{a_{ih}}\right)^{\frac{\gamma\mu}{\beta}} \left(\frac{u_h^P}{u_h}\right)^{-\frac{\mu}{\beta}} (n_{ih} w_h)^{\frac{\mu}{1+\mu}}}{\sum_h (n_{ih} w_h)^{\frac{\mu}{1+\mu}}}\right)}_{\text{(iii) location-specific equilibrium effect}}$$

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MODEL ESTIMATION

Empirical strategy

- **3 parameters guide the quantitative predictions of our model:**

- **Accessiblity to jobs a_{ig}**
  - Need functional form + parameters

- **Ratio γ/β,**
  - i.e. the elasticity of indirect utility with respect to accessibility to jobs,
  - drives the impact of accessibility on bid-rents

- **Parameter μ**
  - drives the impact of changes in bid-rents on changes in population composition

Data (1/2)

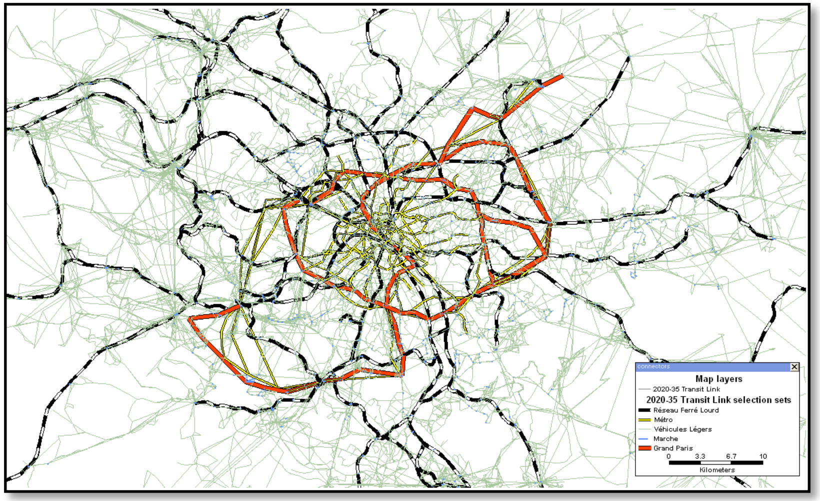
- **Census:**
  - **Historical Census:** workplace and residence location by occupational category for workers aged 25 to 54, at the municipal (‘Communes’) level, between 1968 and 2015
  - **Details from Census 2010**: Commuting flows between municipalities, by occupational category
  - NB: 1,300 municipalities in the Paris region, 431 in the ‘Urban Area’ (defined as contiguous urban land use), 5 occupational categories.
  - 6 Census dates: 1968, 1975, 1982, 1990, 1999, 2010 (5 periods for the estimation)

- **Housing prices and rents in 2010 and 2015**
  - Average rents and transaction prices per square meter for each municipality in 2010 and 2015 (lacoteimmo.com)
  - Geocoded information on all property transactions in 2015 (DVF)

- **Local amenities**
  - natural amenities, including elevation, land uses;
  - infrastructure (dis)amenities, including the proximity to airport or large trans- port infrastructure;
  - (the local housing types and occupation status

Data (2/2)

- **Historical transport times**
  - We compute transport times by public transit between 1968 and 2010 using the MODUS model
  - Information on rail line openings between 1968 and 2010 retrieved from Wikipedia.
  - Assumption: the bus system remained the same.
  - We assume that transport times by car remained constant during the period under scrutiny.



Modus: a 4-step transport model

- the road traffic model uses a network of 89,442 links,
- the public transit model counts 87,217 links

1. Defining accessibility to jobs

- **Assuming C employment centers (indexed by c)**
  - The share of jobs of group g located in center c is: $\tilde{e}_{cg}$
  - w_{ic} is a spatial weight matrix

$$a_{ig} = \sum_{c=1}^{C} \tilde{e}_{cg}\, w_{ic}$$

- **We use an negative exponential form (see e.g. Osland & Thorsen, 2008 ; Ahlfeldt, 2015, Tsivanidis 2019):**

$$w_{ic} = e^{-\tau t_{ic}}$$

  - where t_{ic} is the transport time by public transit between i and c

1. Results – gravity parameter

- **Using OD flows from Census 2010, we estimate the spatial decay parameter τ**

$$\underbrace{\log \rho_{ic}}_{\text{Number of workers commuting from i to c}} = \underbrace{-\tau t_{ic}}_{\text{Transport time}} + \underbrace{\gamma_c + \delta_i}_{\text{Workplace and residence location fixed effects}} + \epsilon_{ic}$$

	Dependent variable:			
	Commuting flow (log)			
	(1)	(2)	(3)	(4)
Time t_{ic}	-0.064^{***}	-0.069^{***}	-0.057^{***}	-0.070^{***}
	(0.0002)	(0.0003)	(0.0004)	(0.0004)
Fixed effects	Yes	Yes	Yes	Yes
$>$ 10 commuter	-	Yes	Yes	Yes
Group selection	All workers	All workers	Only high income	Only low income
Observations	70,103	37,168	19,505	21,082
R^2	0.931	0.978	0.979	0.975

Fixed effects include municipalities of origin and municipalities of destination. Method is Ordinary Least Square. *Note:* Standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01

2. Price-elasticity of accessibility to employment

- **Hedonic pricing model**

$$\log(P_n) = \sum_j \alpha_j h_{jn} + \frac{\gamma}{\beta}\log(a_i) + \sum_k \rho_k \zeta_{ik}$$

- **Accessibility to employment plays a significant positive role in the hedonic pricing model**

- **NB:**
  - We use a measure of accessibility that is not group-specific and encompasses all jobs.
  - We estimate the parameter γ/β using cross-section data

Table 4.H.1: Hedonic pricing model

	Dependent variable:			
	Rent 2010 (log)	Price 2010 (log)	Transac. price 2015 (log)	
	(1)	(2)	(3)	(4)
Units of observation	Municipalities		Apartments	Houses
Built surface (log)			0.841^{***}	0.506^{***}
			(0.007)	(0.009)
Plot surface (log)				0.128^{***}
				(0.003)
Number of rooms dummies			yes	yes
Month dummies	yes	yes	yes	yes
Accessibility to jobs (log)	0.140^{***}	0.170^{***}	0.423^{***}	0.417^{***}
	(0.003)	(0.003)	(0.008)	(0.004)
Paris dummy	0.496^{***}	0.786^{***}	0.425^{***}	1.141^{***}
	(0.019)	(0.021)	(0.010)	(0.041)
Inner suburbs dummy	0.128^{***}	0.189^{***}	0.174^{***}	0.184^{***}
	(0.010)	(0.010)	(0.007)	(0.006)
% social housing	0.005	-0.086^{***}	-1.031^{***}	-0.317^{***}
	(0.024)	(0.026)	(0.019)	(0.022)
Elevation	0.0002^{**}	0.0005^{***}	0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Slope	0.504^{***}	0.833^{***}	-0.597^{***}	0.883^{***}
	(0.130)	(0.142)	(0.166)	(0.141)
Airport $<$ 2km	-0.037^{***}	-0.123^{***}	-0.250^{***}	-0.201^{***}
	(0.013)	(0.014)	(0.009)	(0.009)
Airport $2 < . < 4$km	0.025^{*}	-0.076^{***}	-0.153^{***}	-0.135^{***}
	(0.014)	(0.015)	(0.010)	(0.010)
% water	0.011	0.352^{***}	1.470^{***}	1.323^{***}
	(0.074)	(0.082)	(0.065)	(0.072)
% forest	0.007	-0.011	0.204^{***}	0.084^{***}
	(0.014)	(0.015)	(0.020)	(0.015)
% green urban space	0.142^{***}	0.192^{***}	0.067^{***}	0.212^{***}
	(0.038)	(0.042)	(0.017)	(0.033)
% transp. infra. excl. airport	-0.046	0.099^{*}	0.014	-0.183^{***}
	(0.048)	(0.051)	(0.042)	(0.041)
% dump	-0.350^{***}	-0.532^{***}	-0.752^{**}	-1.232^{***}
	(0.113)	(0.126)	(0.364)	(0.183)
Constant	3.051^{***}	8.418^{***}	9.750^{***}	10.985^{***}
	(0.017)	(0.018)	(0.045)	(0.057)
Observations	3,586	3,606	93,739	37,542
R^2	0.618	0.687	0.475	0.463

% social housing refers to the share of dwellings that is of social housing. Other variables in %X refer to the share of the municipality area occupied by specific land uses. Method is Ordinary Least Square. *Note:* *p<0.1; **p<0.05; ***p<0.01

3. Effect of changes in accessibility on the composition of neighborhoods

$$\log(n_{ig}) = \bar{\mu}_1 \log(a_{ig}) + \bar{\mu}_2 \log(b_{ig}) + \nu_i + \theta_g$$

- **We assume that population adjusts to the equilibrium with a time lag**

- **Observed change in log-population as a function of lagged explanatory variables:**

$$\begin{aligned}\Delta_t \log(\bar{n}_{ig}) = \bar{\mu}_1 \lambda \Delta_t \log(a_{ig}) + \bar{\mu}_1 \bar{\lambda} \Delta_{t-1} \log(a_{ig}) + \bar{\mu}_1 \bar{\lambda} \log(a_{ig,t-2}) \\ + \bar{\mu}_2 \lambda \Delta_t \log(b_{ig}) + \bar{\mu}_2 \bar{\lambda} \Delta_{t-1} \log(b_{ig}) + \bar{\mu}_2 \bar{\lambda} \log(b_{ig,t-2}) \\ - \bar{\lambda} \log(\bar{n}_{ig,t-2}) + \nu_{it} + \theta_{gt}\end{aligned}$$

- **We only include in the regression the value of amenities at the initial date**

Results

- **Positive and significant lagged effects for the period following the change in accessibility.**
  - The effect disappears after one period
  - Simultaneous effects are not significant

- **Check: we run one-period models with respectively anticipated, simultaneous, and lagged effects of change in accessibility to employment on residential composition.**
  - non significant anticipated effects, suggesting that the changes in accessibility are not linked with past changes in residential composition.

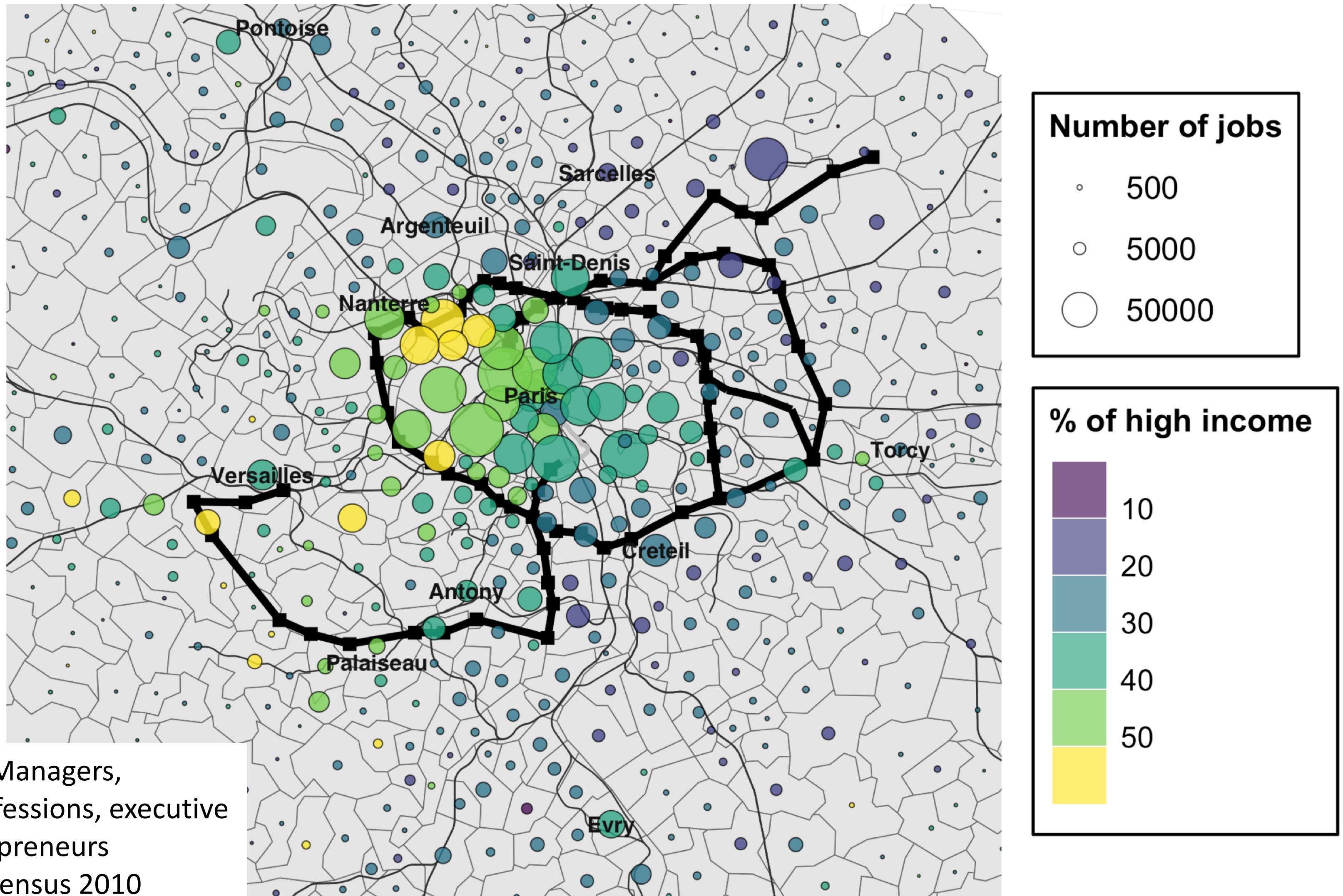
	Dependent variable:			
	$\Delta_t \log(n_{ig})$: Evolution of log-pop. of group g in i			
	(1)	(2)	(3)	(4)
Change in accessibility	0.174	0.766	0.831	1.007**
	(0.672)	(0.504)	(0.524)	(0.506)
Lagged change in accessibility	1.557**	1.450***	1.736***	1.874***
	(0.718)	(0.534)	(0.550)	(0.530)
Initial accessibility (log)	0.233***	0.278***	0.272***	0.358***
	(0.036)	(0.033)	(0.037)	(0.036)
Initial population (log)	−0.122***	−0.017***	−0.034***	−0.100***
	(0.007)	(0.006)	(0.007)	(0.009)
Amenity controls	Yes	-	Yes	Yes
Public housing controls	Yes	-	-	Yes
Location-year fixed effects	Yes	Yes	Yes	Yes
Group-year fixed effects	Yes	Yes	Yes	Yes
Initial population > X hab	1,000	5,000	5,000	5,000
Observations	8,487	4,300	4,300	4,300
R^2	0.479	0.560	0.663	0.637

Change in accessibility is the difference in log-accessibility due to improvements of the transit network. Amenity controls include share of vacant housing, share of secondary or occasional housing, dummies for distance from the center and distance to the closest airport, land use variables, elevation, and slope, with group-period specific coefficients. Public housing controls include the share of public housing in 2015 with group-period specific coefficients. Method is Ordinary Least Square.
Note: Standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01

APPLICATION TO THE GRAND PARIS EXPRESS PROJECT

Anticipating the effect of the GPE on income sorting?

Location and composition of jobs in 2010



High income = Managers, Intellectual professions, executive directors, entrepreneurs
Source: INSEE Census 2010

Anticipating the effect of the GPE on income sorting?

- **We compute changes in transport times induced by the GPE**
  - Using the MODUS model and assumptions about speed/frequency,
  - Assuming no other transport projects (hypothetical scenario).
  - Assuming no changes in jobs

- **3x2x3 possibilities for the different values of the parameters, in both the closed and open city cases (36 simulations)**

Results

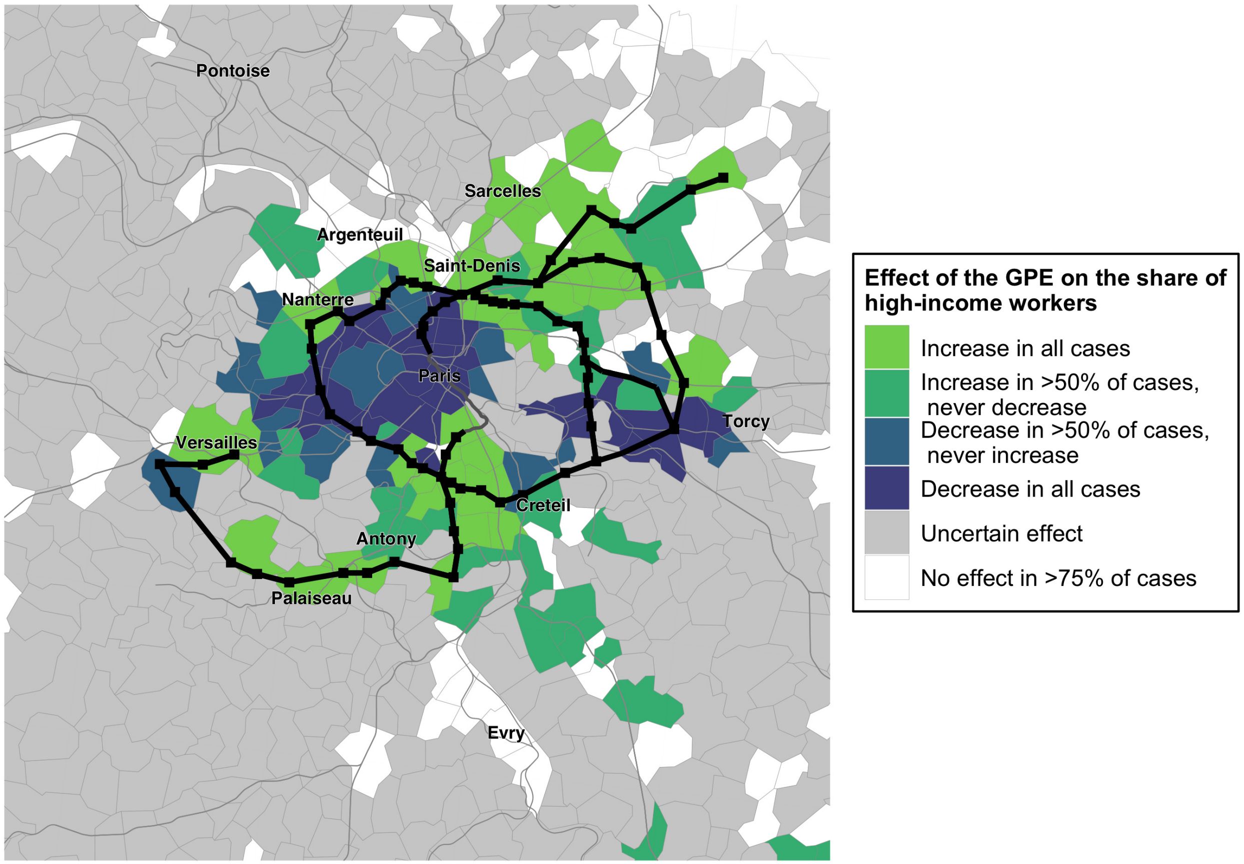


Figure 4.4: Simulated effect of the GPE on the share of high-income workers.

Indicator built on the results of 18 simulations. “Uncertain effect” captures all the municipalities that are not included in the 5 other categories. The distribution of municipalities (below) concerns only municipalities located at less than 200m from a GPE stations. High income occupational categories include entrepreneurs, executive directors, managers, and intellectual professions.

Conclusion

- **The effect of transit on income sorting depends on the geography of the transport network.**

- **In Paris, new lines that increased more accessibility to high-income jobs attracted more high-income group workers, and conversely.**

- **Using estimated parameters, we provide a (coarse) anticipation of the effects of the Grand Paris Express.**

- **Further work:**
  - **Impact on jobs ?** Joint model of residential and employment location choices (cf. Tsivanidis 2019 or Gaigné et al. 2020)
  - Link between income and modal choice (following LeRoy and Sonstelie, 1983).