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High Speed Rails and Knowledge Production - A Global Perspective

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Introduction

Effects of Transportation Development:

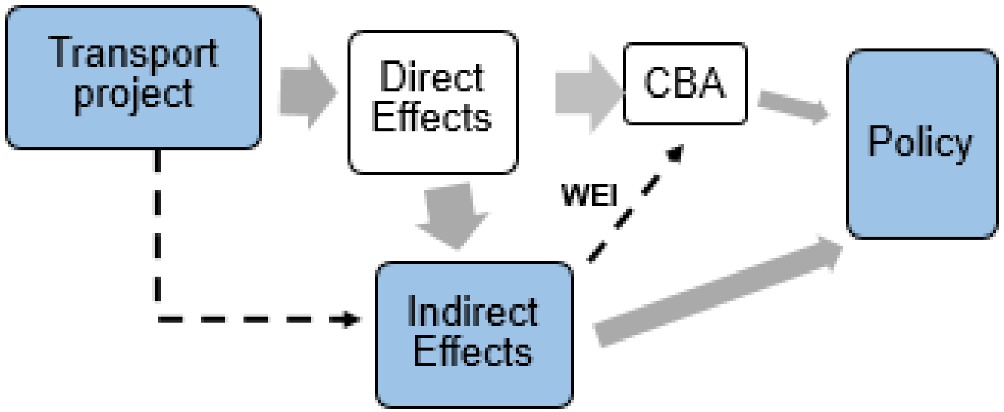
Direct Effects:

- Reduction in Travel Costs and Travel Times

Indirect Effects:

- Benefits outside transportation market on national and regional economies:

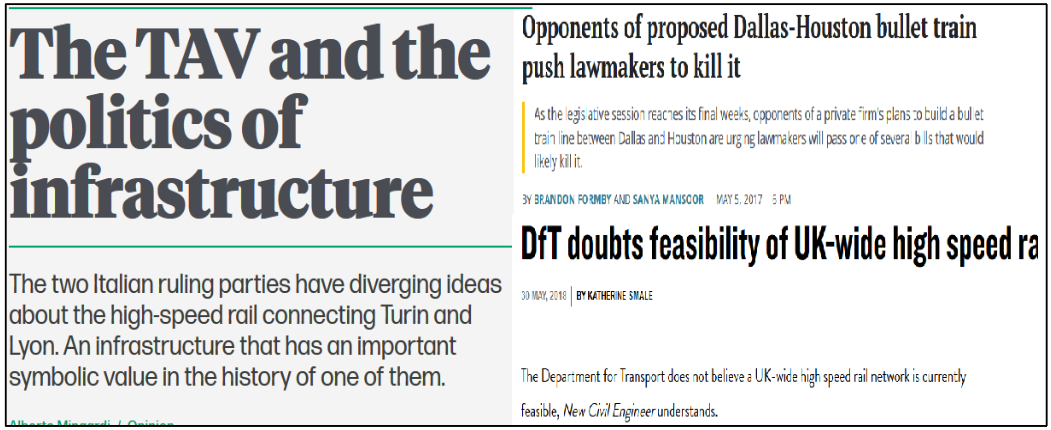
1. Increased amount of trades
2. Industrial productivity
3. Better matching of supplier and buyers
4. Agglomeration of firms and human capital
5. Land values and rights
6. Tax collections



Indirect Effects of transportation can have policy implications

Reliance on Cost Benefit Analyses (CBA)

- Standard Cost Benefit Analyses (CBA) accounts for only:
  - Direct Impacts
  - Economic user benefits (through concept of surpluses)
  - Environmental and Safety benefits (to an extent)
- However, **several indirect effects are not accounted in CBA**



The TAV and the politics of infrastructure

The two Italian ruling parties have diverging ideas about the high-speed rail connecting Turin and Lyon. An infrastructure that has an important symbolic value in the history of one of them.

Opponents of proposed Dallas-Houston bullet train push lawmakers to kill it

As the legislative session reaches its final weeks, opponents of a private firm's plans to build a bullet train line between Dallas and Houston are urging lawmakers will pass one of several bills that would likely kill it.

BY BRANDON FORMBY AND SANYA MANSOOR MAY 5, 2017 5 PM

DfT doubts feasibility of UK-wide high speed ra

30 MAY, 2018 | BY KATHERINE SMALE

The Department for Transport does not believe a UK-wide high speed rail network is currently feasible, *New Civil Engineer* understands.

Source: Smale, 2018; Topham, 2019; Mingardi, 2019

Examples of some highly debated HSR projects

Consequently feasibility decisions using obligatory CBA only are disputed for large projects

HSRs and Knowledge Production

"Innovation is the single, most important component of long-term economic growth"

– Solow (1956)

Concept of Knowledge Economies:

"An economy in which growth is dependent on the quantity, quality, and accessibility of the information available"

-Gerald et. al (2001)

- **Earlier**, the economy was based on the **production of goods**
- Recently, **an important link between economic growth and the concentration of people and firms (agglomerations) is observed**
- The **high concentration** of people and firms **allow ideas to move quickly (knowledge spill overs)** from person to person and from firm to firm
- These **knowledge interactions lead to knowledge production**

Image Source: https://asia.nikkei.com/Business/Companies/Japan-s-supreme-bullet-train-aims-to-impress-Texas-with-speed

Image Source: http://www.sociologydiscussion.com/wp-content/uploads/2013/10/129.jpg

Image Sources: Van Vliet (2003); https://officeforedpolicy.com/2014/02/14/schools-of-innovation-are-coming-arkansas-way-soon/; https://www.cleanpng.com/png-sustainable-development-goals-economic-growth-econ-1538628/

Focus on Knowledge Economy as an Indirect effect of HSRs

Mechanism:

HSRs act as a technological condition that enable sharing of tacit knowledge between researchers through increased opportunities of F-2-F interaction

Objectives of this research:

- **To investigate the associations between HSR development and Knowledge Productivity of countries**
- **To investigate the potential causal relationship from HSR development to Knowledge Productivity of countries**

Popular measure of knowledge production: Patent applications *(Acs and Audretsch, 1989)*

Research Design

This research sets up **two hypotheses**:

1. Countries with better networks of HSRs witness greater amounts of knowledge production due to the HSR's "time-space convergence" effect that enables frequent face-to-face interactions
2. HSR development can have causal effect on national knowledge productivity

Econometric approaches are adopted, where:

For hypothesis 1:

- The **Cobb-Douglas style Knowledge Production Function** is estimated

$$Y_{it} = K_{it}^{\beta_K} \cdot L_{it}^{\beta_L} \cdot g(.)$$

- Introduction of HSRs is treated as a constituent of total factor productivity
- Panel data, spanning from 2007 to 2016 and covering 14 countries where HSRs are operation (as on 2016) are used
- Regression analysis is carried out using method of OLS

For hypothesis 2:

- Two quasi-experimental methods are applied for analyzing the short & long term treatment effects
  1. Difference-in-differences for continuous time frame
  2. Matching techniques of propensity score matching(PSM) and genetic matching(GM)
- An unbalanced panel data for duration of 39 years, from 1980-2018, and covering 59 countries are used
- This data covers maximum possible number of upper middle-income and high-income group countries (World Bank classification based on GNI per capita)

Data

Variable	Unit	Source
KPF estimation		
Patent applications per capita	Patents/million population	WIPO statistics
HSR Length per capita	Route kilometers of rails/million population	UIC
R&D capital expenditure per capita	Gross Domestic Expenditure on R&D at current PPP $/million population	OECD *i*-Library
R&D human capital per capita	Total R&D personnel (FTE) /million population	OECD *i*-Library
Quality of roads	Categorical: 1 Worst -7 Best	WEF
Quality of air transportation infrastructure	Categorical: 1 Worst -7 Best	WEF
Intellectual property protection	Categorical: 1 Worst -7 Best	WEF
Quality of the education system	Categorical: 1 Worst -7 Best	WEF
Capacity for innovation	Categorical: 1 Worst -7 Best	WEF
Macroeconomic environment	Categorical: 1 Worst -7 Best	WEF
Natural experiments		
Gross domestic product per capita	1000 Current $/capita	World Bank
Gross capital formation per capita	1000 Current $/capita	World Bank
Gross national income per capita	1000 Current $/capita	World Bank
Gross national expenditure per capita	1000 Current $/capita	World Bank
R&D expenditure per capita	Current $/capita	World Bank
Researchers in R&D per capita	Number per 1000 people	World Bank
Graduates from tertiary education	Million people	World Bank
Population density	1000 people/km^2	World Bank
Urban population growth	Annual %	World Bank
Ridership of air transportation	Ten-Million pax. carried/year	World Bank
Ridership of rail transportation	Million pax.-kms	World Bank
Mobile cellular subscriptions per capita	per 100 population	World Bank

Estimating Knowledge Production Function

The **Cobb-Douglas style Knowledge Production Function** (following Griliches, 1979 and Charlot et. al., 2015) is as follows:

$$\boldsymbol{Y_{it} = K_{it}^{\beta_K} \cdot L_{it}^{\beta_L} \cdot g(.)}$$

Where,

$\boldsymbol{\beta_K}$ **and** $\boldsymbol{\beta_L}$ are unknown coefficients;

Y_{it} is **patent applications per capita** of country i at time t;

K_{it} represents **R&D capital expenditure per capita** of country i at time t;

L_{it} represents **human capital devoted to R&D per capita** in country i at time t;

g(.) represents the **total factor productivity (TFP)** function, as follows

$$\boldsymbol{g(f_{it}, X_{it}) = exp\left(\beta_f f_{it} + \sum_n \beta_n X_{itn} + \mu_i + \rho_t + \varepsilon_{it}\right)}$$

Where, $\boldsymbol{f_{it}}$ **is the HSR length per capita** of country *i* at time *t*; $\boldsymbol{X_{itn}}$ **is a matrix containing other control variables**; ε_{it} is an error component following the normal distribution; $\boldsymbol{\mu_i}$ **and** $\boldsymbol{\rho_t}$ **are the country and year specific fixed effects**

$$\boldsymbol{lnY_{it} = \beta_K lnK_{it} + \beta_L lnL_{it} + \beta_f f_{it} + \sum_n \beta_n X_{itn} + \mu_i + \rho_t + \varepsilon_{it}}$$

Estimating Short-term Treatment Effects

Difference-in-differences for continuous time frame:

- **Treatment group** (HSRs are introduced within the study period): **15 countries**;
- **Control group** (either no HSR introduction or HSR already existed on 1980): **44 countries**
- **Study period: 1989 to 2018 (29 years)**
- **Pre-existing differences in values of Patent productivity is also checked** using the data for 10 years before the start of study period, i.e. 1980 to 1989 (following Yu et al., 2012; Zheng et al., 2017)

$$lnY_{it} = \omega_{treat} Z_i \cdot YB_t + \omega_{did} Z_i \cdot YA_{it} + \sum_k \theta_k X_{itk} + \pi_i + \tau_t + \epsilon_{it}$$

Where,

$\mathbf{Y_{it}}$ represents the knowledge production per capita of country i at year t;
$\mathbf{Z_i}$ is a dummy, which equals 1 if the country belongs to the treatment group and 0 otherwise;
$\mathbf{YB_{it}}$ is the dummy, which equals 1 if the year t corresponds to the one prior to study duration and 0 otherwise;
$\mathbf{YA_{it}}$ is the dummy, which takes value 1 if the year t is after the introduction of HSR and 0 otherwise;
$\mathbf{X_{it}}$ is a vector containing k control variables;
$\boldsymbol{\pi_i}$ and $\boldsymbol{\tau_t}$ are the country and year specific fixed effects, respectively for accounting heterogeneities;
$\boldsymbol{\epsilon_{it}}$ is the error term; and $\boldsymbol{\omega_{treat}}$, $\boldsymbol{\omega_{did}}$, **and** $\boldsymbol{\theta_k}$ are unknown coefficients

Estimating Long-term Treatment Effects

Multivariate matching methods

- Matching enable the **comparison among similar Treatment & Control group countries only**
- **Nine macro-economic variables are used** for matching treatment and control group countries
- **Study period: 1990 to 2015 (26 years)**
- **Treatment group:** 10 countries; **Control group:** 19 countries

Propensity Score Matching:

Propensity score (PS) is the conditional probability of assignment to treatment given the covariates (Diamond and Sekhon, 2013), and is defined as

$$\boldsymbol{h}(.) = \boldsymbol{Pr}(\boldsymbol{Z_i}|\boldsymbol{M_i})$$

where,

$\mathbf{h}(.)$ represents a PS function (a logit function);

$\mathbf{Z_i}$ represents the treatment assignment, which equals 1 if an observation falls in to the treatment group and 0 if it falls into the control group; and

$\mathbf{M_i}$ is a set of observed confounding variables.

Genetic Matching:

- GM is a generalization of a multivariate distance matric that is based on Mahalanobis distance (MD) (Diamond and Sekhon, 2013)
- GM uses a genetic-algorithm-based search to maximize the balance of observed covariates post matching (Diamond and Sekhon, 2013)

$$GMD(M_i, M_j) = \sqrt{(M_i - M_j)^T (S^{-0.5})^T W S^{-0.5} (M_i - M_j)}$$

where,

$\boldsymbol{S}$ is the sample covariance matrix;

$\mathbf{W}$ is a positive definite weight matrix.

Findings from three analyses

KPF estimation:

- **HSRs length per capita has a significantly positive association with knowledge productivity** and its estimated elasticity is about **5%** in both models.
- The **interaction terms of HSR length per capita with the quality of air transportation** infrastructure is estimated to have significantly negative association with knowledge productivity with elasticities of about 1 %.
- This **reflects that the air transportation acts as a competitor against HSRs** in influencing knowledge productivity.

DID for continuous time frame:

- **The short-term treatment effect** (parameter estimate for *Z.YA*) is estimated to be **significantly positive** with elasticities ranging from about 16% to 24%. This shows that the **countries that introduced HSRs gained positive effects on knowledge productivity**
- The **parameter estimate of the interaction variable of HSR treatment and air transportation** is found to be significantly negative, which means that **air transportation is a potential competitor of HSRs**.

Multivariate matching study:

- The **PSM results show weakly positive ATT and ATE estimates**. However, the **estimates of ATT and ATE from GM showed significantly positive and weakly positive results**, respectively
- It should be noted that the **quality of matching with PSM indicated poor balance between treatment and control groups** and raised concerns of reliability of PSM estimates
- However, **by using GM, a good balance between control and treatment groups in post matching is obtained**
- The significantly positive estimate of ATT from GM technique showed an **increase of about 350 patent applications per million population**
- This may suggest that the **existence of HSR network in a country has significantly positive impacts on the knowledge productivity** in long term

Discussions and Concluding Remarks

- Despite the challenges that the long history of HSRs and the heterogeneities between the 59 countries has put forward, **this research developed macro-economic evidences for the effects of HSRs' development on national innovation from a global perspective**.
- Even after getting evidences for significant positive results in various empirical analyses, **there are issues that are not well understood and accounted:**
  - **Ambiguity in mechanisms** through which HSRs impact the knowledge production
  - Several **critical variables that may affect knowledge production could not be included** due to data availability challenges over the long history of HSRs
  - **Other forms of knowledge slipovers** that arise from **physical and non-physical proximities** are not considered in this research
  - Another issue is the **use of patent application as a measure for knowledge production**
- The **investigation of these detailed insights are critical** and require **meso- and micro-level studies that considers local contexts (industrial as well as regional)** to greater degrees
- This may facilitate the **formulation of inter-linked policies for regional transportation and innovation**

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Appendix 1 : List of countries covered (contd.)

Country	Code	Year of Start	KPF estimation	DID analysis	Matching
Austria	AT	1990	✓	Treatment	Treatment
Belgium	BE	1997	✓	Treatment	N.A.
Switzerland	CH	2004	✓	Treatment	Treatment
China	CHN	2003	✓	Treatment	Treatment
Germany	DE	1991	✓	Treatment	N.A.
Spain	ES	1992	✓	Treatment	Treatment
Finland	FI	1995	✓	Treatment	Treatment
Republic of Korea	KR	2004	✓	Treatment	N.A.
Norway	NO	1998	✓	Treatment	Treatment
Russian Federation	RU	2013	✓	Treatment	N.A.
Turkey	TR	2009	✓	Treatment	Treatment
Netherlands	NL	2006	N.A.	Treatment	Treatment
Poland	PL	2015	N.A.	Treatment	N.A.
United Kingdom	GB	2003	N.A.	Treatment	Treatment
United States of America	US	2000	N.A.	Treatment	Treatment
France	FR	1981/83	✓	Control	Control
Italy	IT	1977	✓	Control	Control
Japan	JP	1964	✓	Control	Control
Denmark	DK	2019	N.A.	Control	Control
Albania	AL	No HSR	N.A.	Control	N.A.
Algeria	DZ	No HSR	N.A.	Control	N.A.
Australia	AU	No HSR	N.A.	Control	N.A.
Bosnia and Herzegovina	BA	No HSR	N.A.	Control	N.A.
Botswana	BW	No HSR	N.A.	Control	N.A.
Brazil	BR	No HSR	N.A.	Control	Control
Bulgaria	BG	No HSR	N.A.	Control	Control
Canada	CA	No HSR	N.A.	Control	Control
Chile	CL	No HSR	N.A.	Control	N.A.
Croatia	HR	No HSR	N.A.	Control	N.A.
Cuba	CU	No HSR	N.A.	Control	N.A.
Czech Republic	CZ	No HSR	N.A.	Control	N.A.

Appendix 1 : List of countries covered (contd.)

Country	Code	Year of Start	KPF estimation	DID analysis	Matching
Estonia	EE	No HSR	N.A.	Control	N.A.
Georgia	GE	No HSR	N.A.	Control	N.A.
Greece	GR	No HSR	N.A.	Control	Control
Hungary	HU	No HSR	N.A.	Control	N.A.
Iran (Islamic Republic of)	IR	No HSR	N.A.	Control	Control
Iraq	IQ	No HSR	N.A.	Control	N.A.
Ireland	IE	No HSR	N.A.	Control	Control
Israel	IL	No HSR	N.A.	Control	N.A.
Jordan	JO	No HSR	N.A.	Control	Control
Kazakhstan	KZ	No HSR	N.A.	Control	N.A.
Latvia	LV	No HSR	N.A.	Control	N.A.
Lithuania	LT	No HSR	N.A.	Control	N.A.
Luxembourg	LU	No HSR	N.A.	Control	N.A.
Malaysia	MY	No HSR	N.A.	Control	Control
Montenegro	ME	No HSR	N.A.	Control	N.A.
New Zealand	NZ	No HSR	N.A.	Control	Control
North Macedonia	MK	No HSR	N.A.	Control	N.A.
Peru	PE	No HSR	N.A.	Control	Control
Portugal	PT	No HSR	N.A.	Control	Control
Romania	RO	No HSR	N.A.	Control	N.A.
Serbia	RS	No HSR	N.A.	Control	N.A.
Slovakia	SK	No HSR	N.A.	Control	N.A.
Slovenia	SI	No HSR	N.A.	Control	N.A.
South Africa	ZA	No HSR	N.A.	Control	Control
Sri Lanka	LK	No HSR	N.A.	Control	Control
Sweden	SE	No HSR	N.A.	Control	Control
Thailand	TH	No HSR	N.A.	Control	N.A.
Uruguay	UY	No HSR	N.A.	Control	Control