On the modal shift from motorway to high-speed rail: evidence from Italy

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Overview

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- Methodology and data
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- Since the end of the twentieth century, the development of high-speed rail (HSR) has been one of the central features of many European countries.
- Reasons behind these huge HSR investments are: reduction of travel time, boosting "green" solutions, facilitate freight transportation.
- The main European HSR networks are in France (TGV), Spain (AVE), Germany (ICE), and Italy (TAV).
- HSR development is supported and co-financed by the EU with the aim of tripling its length by 2030 to achieve a 50% shift of medium-distance passenger and freight journeys from road to rail by 2050.

Motivations for studying Motorway-HSR modal shift

- The literature is scant, as most of previous studies focused on:
 - The inter-modal demand competition (*Román et al., 2007; Yang and Zhang, 2012; Behrens and Pels, 2012; Capozza, 2016)*, supply competition (*Dobruszkes, 2011; Jiménez and Betancor, 2012*), and cooperation (*Givoni and Banister, 2006; Albalate et al., 2015*) between HSR and air services.
 - The intra-modal competition between HSR operators (*Cascetta and Coppola, 2014; Bergantino et al., 2015; Beria et al., 2016*).
- It is a relevant issue in any CBA of HSR investments in terms of:
 - Forecasting demand in rail projects (*Flyvbjerg et al., 2005; Flyvbjerg, 2007*).
 - Estimating the environmental impact of introducing HSR services (*De Rus and Nombela, 2007; De Rus, 2011*).

Research question

- The aim is to analyse whether the HSR expansion in Italy led to a modal shift from motorway to HSR services by empirically testing:
 - i) Whether HSR openings next to some motorway sectors has reduced the total km traveled by light vehicles on those sectors during the period 2001-2017.
 - ii) Whether this reduction has been persistent or even stronger after the opening of on-track competition between the incumbent *Trenitalia* and the new operator *Nuovo Trasporto Viaggiatori*.
- Why Italy?
 - It is the first case of competition among nonsubsidized HSR operators.
 - HSR competes also with the car because large metropolitan areas are at relatively short distances between each other.

Literature review on Motorway-HSR modal shift

- International evidence after HSR introduction:
 - On average, the reduction in the number of car passengers in the routes examined by a set of papers is in the order of 10-20% (*Givoni and Dobruszkes, 2013*).
 - In the Madrid-Seville link, car passengers increased by 23% (European Commission, 1998).
 - In the Korean and Taiwanese routes, road transport retains high market shares (Cho and Chung, 2008; Cheng, 2010).
- Italian evidence after HSR introduction:
 - in March 2008 in the Rome-Naples link, the percentages of HSR users who used motorway before HSR opening were 7.8% on weekdays, 12.4% on Saturday, and 14.4% on Sunday (*Cascetta et al., 2011*).
 - Between 2009 and 2013, variation in the motorway traffic was substantially different if observed within the HSR catchment area (-19%) with respect to the national trend (-10%) (*Cascetta and Coppola, 2015*).

Methodology and data

• We carried out a generalized diff-in-diff estimation by using a unique panel dataset (2001-2017) that exploits the heterogeneous traffic data within all tolled motorway sectors (51) in a quasi-experimental setting.

Table 1: Data collection and sources

Variable	Definition	Source
Vehicles – Km	Total km traveled by light vehicles on motorway sector i in year t	AISCAT
Vehicles	Light vehicles per capita of municipalities located within 15 km arc distance from exits of a motorway sector i in year t	ACI, ISTAT
GDP	Weighted average of gross domestic product per capita in the regions of transit for a motorway sector i in year t	ISTAT
Airport size	Passengers carried by domestic flights departed from airports located within 50 km arc distance from exits of a motorway sector i in year t	Eurostat
Sector length	Length of a motorway sector <i>i</i> in year <i>t</i>	AISCAT
Toll	Revenues per km traveled earned by the highway concession company of a motorway sector i in year t	AISCAT
Fuel	Weighted average cost of fuel in year t	ACI, MiSE

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$$log(Vehicles - Km)_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Vehicles_{it} + \beta_3 GDP_{it} + \beta_4 Airport \ size_{it} + \beta_5 Sector \ length_{it} + \beta_6 Toll_{it} + \beta_7 Fuel_t + \alpha_i + \delta_t + \epsilon_{it}$$
(1)

• X is a continuous variable that takes values between 0 and 1:

- Whether a full or a partial HS line opened next to a motorway sector i in year t (HSR^{Opening}).
- Whether on-track competition started on a full or a partial HS or conventional line next to motorway sector *i* in year *t* (*HSR*^{Competition}).
- α and δ are motorway sector and year fixed effects.
- ϵ are clustered standard errors at the highway level.

Map of *HSR^{Opening}* and *HSR^{Competition}* up to 2017



Descriptive trend: HSR^{Opening}

Figure 3: Evolution of the total km traveled versus HSR^{Opening} expansion



Descriptive trend: HSR^{Competition}

Figure 4: Evolution of the total km traveled versus HSR^{Competition} expansion



Parallel trend: HSR^{Opening}

Figure 5: Average km traveled on sectors with and without HSR^{Opening}



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Parallel trend: HSR^{Competition}

Figure 6: Average km traveled on sectors with and without HSR^{Competition}



Baseline estimates: HSR^{Opening}

Table 2: Effect of HSR^{Opening} on the km traveled by light vehicles

	log(Vehicles – Km)					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Opening}	0.272	0.283	0.089***	0.086***	0.054**	0.054**
	(0.186)	(0.193)	(0.021)	(0.021)	(0.021)	(0.021)
Vehicles	-1.214***	-1.024***	0.211**	0.160	0.145	0.158
	(0.201)	(0.263)	(0.102)	(0.143)	(0.088)	(0.137)
GDP	0.015	0.016	0.013***	0.017***	0.014**	0.013
	(0.016)	(0.017)	(0.003)	(0.004)	(0.006)	(0.008)
Airport size	0.056***	0.053***	0.014	0.014	-0.019**	-0.020**
	(0.016)	(0.016)	(0.010)	(0.010)	(0.008)	(0.008)
Sector length	0.009***	0.009***	0.010***	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)
Toll		-0.028		0.006		-0.002
		(0.032)		(0.007)		(0.007)
Fuel		0.001		-0.000		
		(0.002)		(0.000)		
Constant	5.864***	5.765***	5.096***	4.992***	5.144***	5.171***
	(0.530)	(0.646)	(0.298)	(0.286)	(0.348)	(0.381)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	867	867	867	867	867	867
R^2	0.661	0.667	0.402	0.407	0.614	0.614

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Baseline estimates: HSR^{Competition}

Table 3: Effect of HSR^{Competition} on the km traveled by light vehicles

	log(Vehicles – Km)					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Competition}	0.300*	0.324*	0.070**	0.066**	0.071**	0.071**
	(0.170)	(0.177)	(0.027)	(0.028)	(0.032)	(0.033)
Vehicles	-1.213***	-1.016***	0.202*	0.151	0.155*	0.163
	(0.199)	(0.263)	(0.106)	(0.150)	(0.087)	(0.132)
GDP	0.015	0.016	0.012***	0.017***	0.015**	0.014
	(0.016)	(0.017)	(0.004)	(0.004)	(0.007)	(0.008)
Airport size	0.060***	0.057***	0.022*	0.021*	-0.015*	-0.015*
	(0.015)	(0.015)	(0.011)	(0.011)	(0.008)	(0.008)
Sector length	0.009***	0.009***	0.010***	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Toll		-0.029		0.006		-0.001
		(0.032)		(0.007)		(0.007)
Fuel		0.001		0.000		
		(0.002)		(0.000)		
Constant	5.867***	5.759***	5.107***	4.986***	5.104***	5.120***
	(0.534)	(0.644)	(0.316)	(0.294)	(0.350)	(0.384)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	867	867	867	867	867	867
R^2	0.660	0.666	0.389	0.394	0.620	0.621

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Robustness checks

• Parallel Trend Assumption and timing of effects.



Placebo regressions.



• Stable Unit Treatment Value Assumption (SUTVA).



Discussion

- No contribution of a modal shift from motorways to the excellent demand performances of the Italian HSR network.
 - Main sources of HSR passengers are conventional rail, air transport, and induced demand (*Givoni and Dobruszkes, 2013*).
 - Car attractiveness is based on the door-to-door travel time rather than the station-to-station travel time. Access and egress times are still determining factors in mode choice decision (*Moyano et al., 2018*).
- Slightly positive impact of HSR expansion on motorway traffic.
 - Possible positive impact of HSR expansion on the surrounding economic activities.
 - HSR expansion might jeopardise conventional rail services and lead to an unintended increase in car dependency (*Sánchez-Mateos and Givoni*, 2012). Fully versus mixed HS services (*Beria and Grimaldi*, 2011).

• Limitations:

- No data on conventional rail passengers.
- Aggregate Vehicles Km data.
- Further research:
 - Study the impact of HSR expansion on conventional rail services.
 - Perform the same analysis for heavy vehicles, once freight trains will start to use the new HS lines.

Thank you for your attention

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Motorway-HSR modal shift

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Leads and Lags estimates: HSR^{Opening} • Back

Figure 7: Timing of HSR^{Opening} effect on the km traveled by light vehicles



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Motorway-HSR modal shift

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Leads and Lags estimates: HSR^{Competition}

Figure 8: Timing of HSR^{Competition} effect on the km traveled by light vehicles



Motorway-HSR modal shift

Table 4: Placebo effect of HSR^{Opening} on the km traveled by light vehicles

	log(Vehicles – Km)					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Opening}	-0.512***	-0.524***	0.017	0.017	-0.005	-0.006
	(0.152)	(0.155)	(0.041)	(0.042)	(0.044)	(0.042)
Vehicles	-1.113***	-0.973***	0.156	0.096	0.116	0.128
	(0.231)	(0.289)	(0.097)	(0.138)	(0.080)	(0.129)
GDP	0.010	0.012	0.010**	0.016***	0.013*	0.012
	(0.015)	(0.016)	(0.004)	(0.003)	(0.007)	(0.008)
Airport size	0.064***	0.061***	0.016	0.015	-0.019**	-0.019**
	(0.014)	(0.014)	(0.010)	(0.010)	(0.008)	(0.008)
Sector length	0.009***	0.009***	0.010***	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Toll		-0.023		0.007		-0.002
		(0.033)		(0.008)		(0.007)
Fuel		0.003*		0.000		
		(0.002)		(0.000)		
Constant	6.020***	5.656***	5.201***	5.030***	5.172***	5.196***
	(0.497)	(0.587)	(0.331)	(0.311)	(0.364)	(0.394)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	867	867	867	867	867	867
R^2	0.681	0.686	0.372	0.378	0.603	0.603

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Table 5: Placebo effect of HSR^{Competition} on the km traveled by light vehicles

	$\log(Vehicles - Km)$					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Competition}	-0.409**	-0.401**	-0.023	-0.034	-0.004	-0.004
	(0.155)	(0.159)	(0.036)	(0.039)	(0.041)	(0.041)
Vehicles	-1.161***	-1.030***	0.180*	0.116	0.115	0.126
	(0.220)	(0.274)	(0.106)	(0.150)	(0.087)	(0.136)
GDP	0.011	0.014	0.007**	0.014***	0.013*	0.012
	(0.016)	(0.017)	(0.004)	(0.004)	(0.007)	(0.008)
Airport size	0.063***	0.061***	0.018*	0.017*	-0.019**	-0.019**
	(0.014)	(0.015)	(0.009)	(0.010)	(0.008)	(0.008)
Sector length	0.009***	0.009***	0.010***	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Toll		-0.022		0.008		-0.002
		(0.033)		(0.009)		(0.007)
Fuel		0.003		0.000		
		(0.002)		(0.000)		
Constant	5.976***	5.681***	5.238***	5.055***	5.173***	5.196***
	(0.532)	(0.622)	(0.327)	(0.307)	(0.370)	(0.397)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	867	867	867	867	867	867
R^2	0.665	0.669	0.374	0.382	0.603	0.603

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Sub-sample estimates: HSR^{Opening} • Back

Table 6: Sub-sample effect of HSR^{Opening} on the km traveled by light vehicles

	$\log(Vehicles - Km)$					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Opening}	0.443**	0.465**	0.095***	0.094***	0.060***	0.060***
	(0.173)	(0.193)	(0.020)	(0.021)	(0.021)	(0.020)
Vehicles	-1.140***	-1.264***	0.308***	0.224	0.205**	0.192
	(0.214)	(0.287)	(0.075)	(0.188)	(0.092)	(0.218)
GDP	0.012	0.009	0.016***	0.018***	0.016	0.016
	(0.019)	(0.020)	(0.004)	(0.006)	(0.010)	(0.010)
Airport size	0.046**	0.048**	0.011	0.015	-0.016*	-0.015
	(0.019)	(0.020)	(0.010)	(0.009)	(0.009)	(0.010)
Sector length	0.009***	0.009***	0.011***	0.011***	0.011***	0.011***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Toll		0.021		0.007		0.001
		(0.032)		(0.011)		(0.012)
Fuel		-0.003		-0.000		
		(0.002)		(0.000)		
Constant	5.848***	6.205***	4.766***	4.764***	4.859***	4.852***
	(0.597)	(0.792)	(0.279)	(0.257)	(0.409)	(0.398)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	595	595	595	595	595	595
R^2	0.690	0.694	0.495	0.502	0.643	0.643

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Sub-sample estimates: HSR^{Competition} Back

Table 7: Sub-sample effect of HSR^{Competition} on the km traveled by light vehicles

	$\log(Vehicles - Km)$					
	(1)	(2)	(3)	(4)	(5)	(6)
HSR ^{Competition}	0.414**	0.429**	0.068***	0.064**	0.067**	0.067**
	(0.153)	(0.171)	(0.021)	(0.023)	(0.026)	(0.026)
Vehicles	-1.193***	-1.168***	0.292***	0.212	0.220***	0.216
	(0.191)	(0.261)	(0.070)	(0.194)	(0.076)	(0.199)
GDP	0.020	0.020	0.014***	0.016***	0.016	0.016
	(0.021)	(0.022)	(0.004)	(0.005)	(0.010)	(0.010)
Airport size	0.035**	0.035**	0.024**	0.027***	-0.008	-0.008
	(0.014)	(0.014)	(0.009)	(0.008)	(0.007)	(0.009)
Sector length	0.010***	0.010***	0.013***	0.012***	0.012***	0.012***
	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Toll		-0.003		0.007		0.000
		(0.032)		(0.011)		(0.012)
Fuel		-0.000		-0.000		
		(0.002)		(0.000)		
Constant	5.662***	5.720***	4.689***	4.676***	4.720***	4.718***
	(0.648)	(0.827)	(0.415)	(0.365)	(0.546)	(0.519)
Motorway sector	No	No	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes
Observations	612	612	612	612	612	612
R^2	0.701	0.702	0.451	0.457	0.635	0.635

OLS estimates. Standard errors clustered at the highway level. ***p<0.01, **p<0.05, *p<0.1.

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Table 8: Opening dates of HSR^{Opening} up to 2017

Section	Opening year(s)	Length (km)	Max speed (km/h)	Motorway sector
Turin–Salerno axis		873.5		
Turin–Novara	February 2006	86.4	300	A4 Torino–Milano
Novara–Milan	December 2009	38.6	300	A4 Torino–Milano
Milan–Bologna	December 2008	182.0	300	A1 Milano–Bologna
Bologna–Florence	December 2009	78.5	300	A1 Bologna–Firenze
Florence-Rome	1977-1992	254.0	250	A1 Firenze–Roma
Rome–Gricignano	December 2005	186.0	300	A1 Roma–Napoli and
				A1 Coll. Firenze–Roma–Napoli
Gricignano–Naples	December 2009	19.0	300	A1 Roma–Napoli
Naples-Salerno	June 2008	29.0	250	A3 Napoli–Salerno
Milan–Venice axis		91.6		
Milan–Treviglio	June 2007	27.0	200	A4 Milano–Brescia
Treviglio–Brescia	December 2016	39.6	300	A4 Milano–Brescia
Padua–Venice	March 2007	25.0	220	A4-A57 Padova-Mestre
Other lines [*]		114.0		
Verona–Bologna	July 2009	114.0	200	A22 Verona–Modena

Notes: [*]Short sectors of the Naples-Bari and Palermo-Messina-Catania lines were upgraded late in 2017. Sources: Own elaboration based on Beria et al. (2018), *RFI* website, and *Trenitalia*'s financial statements.

Section	Opening year(s)	Length (km)	Max speed (km/h)	Motorway sector
Turin–Salerno axis		873.5		
Turin–Milan	December 2012	125.0	300	A4 Torino–Milano
Milan–Bologna	April 2012	182.0	300	A1 Milano–Bologna
Bologna–Florence	April 2012	78.5	300	A1 Bologna–Firenze
Florence–Rome	April 2012	254.0	250	A1 Firenze–Roma
Rome–Naples	April 2012	205.0	300	A1 Roma–Napoli and
				A1 Coll. Firenze–Roma–Napoli
Naples–Salerno	August 2012	29.0	250	A3 Napoli–Salerno
Milan-Venice axis		88.0		
Brescia–Verona	March 2016	63.0	Conventional line	A4 Brescia–Padova
Padua–Venice	October 2012	25.0	220	A4-A57 Padova–Mestre
Other lines		441.0		
Verona–Bologna	December 2015	114.0	200	A22 Verona–Modena
Bologna–Padua	October 2012	123.0	Conventional line	A13 Bologna–Padova
Bologna–Ancona [*]	December 2013	204.0	Conventional line	A14 Bologna–Ancona

Table 9: Opening dates of HSR^{Competition} up to 2017

Notes: [*]On-track competition lasted until December 2014, then *NTV* kept only summer services. *Sources*: Own elaboration based on Bergantino et al. (2015), *NTV* website, and *NTV*'s financial statements.