Universidad de Los Andes

Facultad de Economía

III Seminario internacional
Análisis costo beneficio y calidad de la inversión pública

Bogotá, 16 de julio 2010

Evaluación económica de la inversión en infraestructuras

¿Es socialmente rentable la inversión en alta velocidad?

Ginés de Rus

Universidad de Las Palmas, Spain
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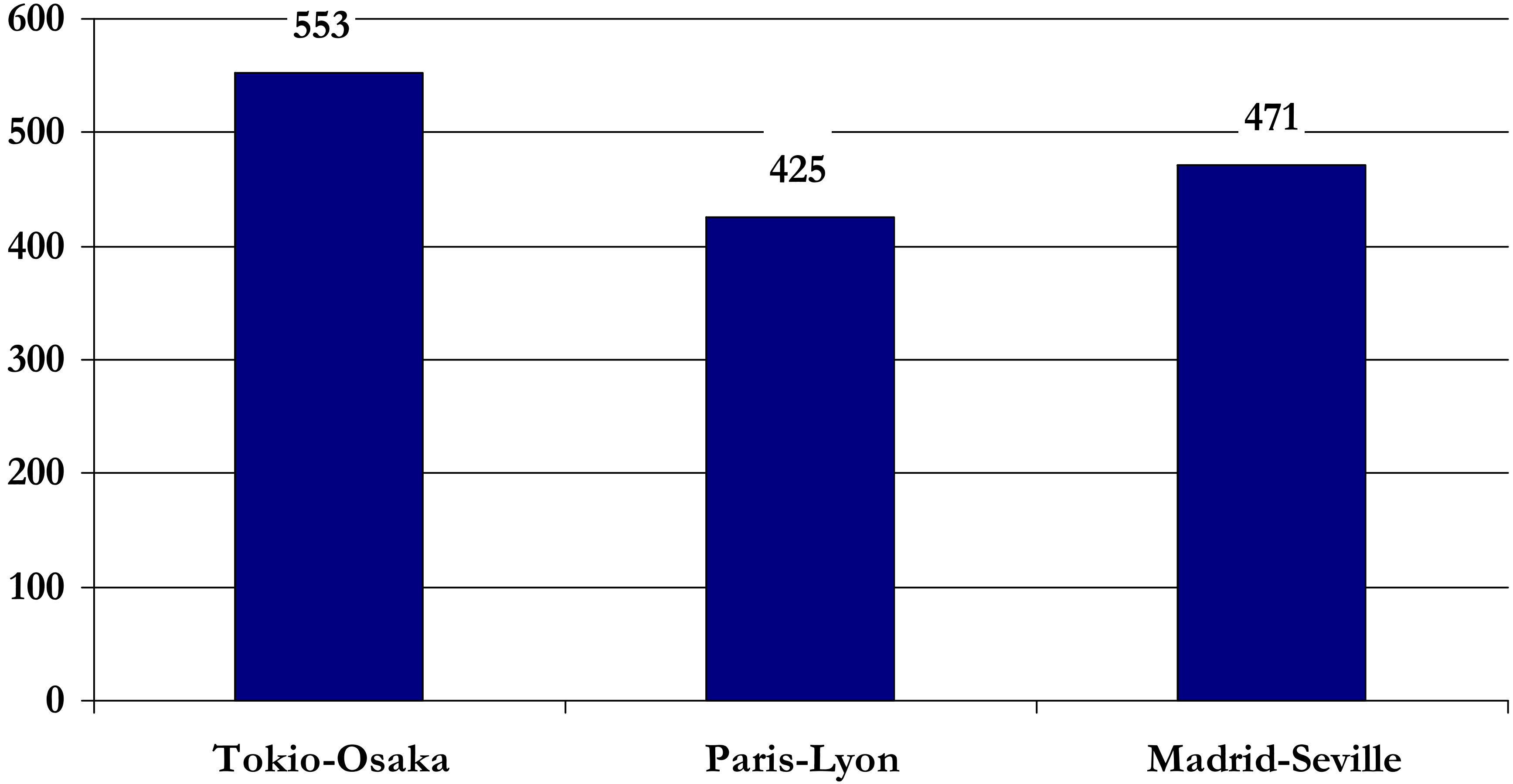
Características de las infraestructuras

- Larga vida
- Inversiones costosas
- Costes irrecuperables
- Utilizan recursos naturales
- Incertidumbre de demanda
- Los gobiernos deciden

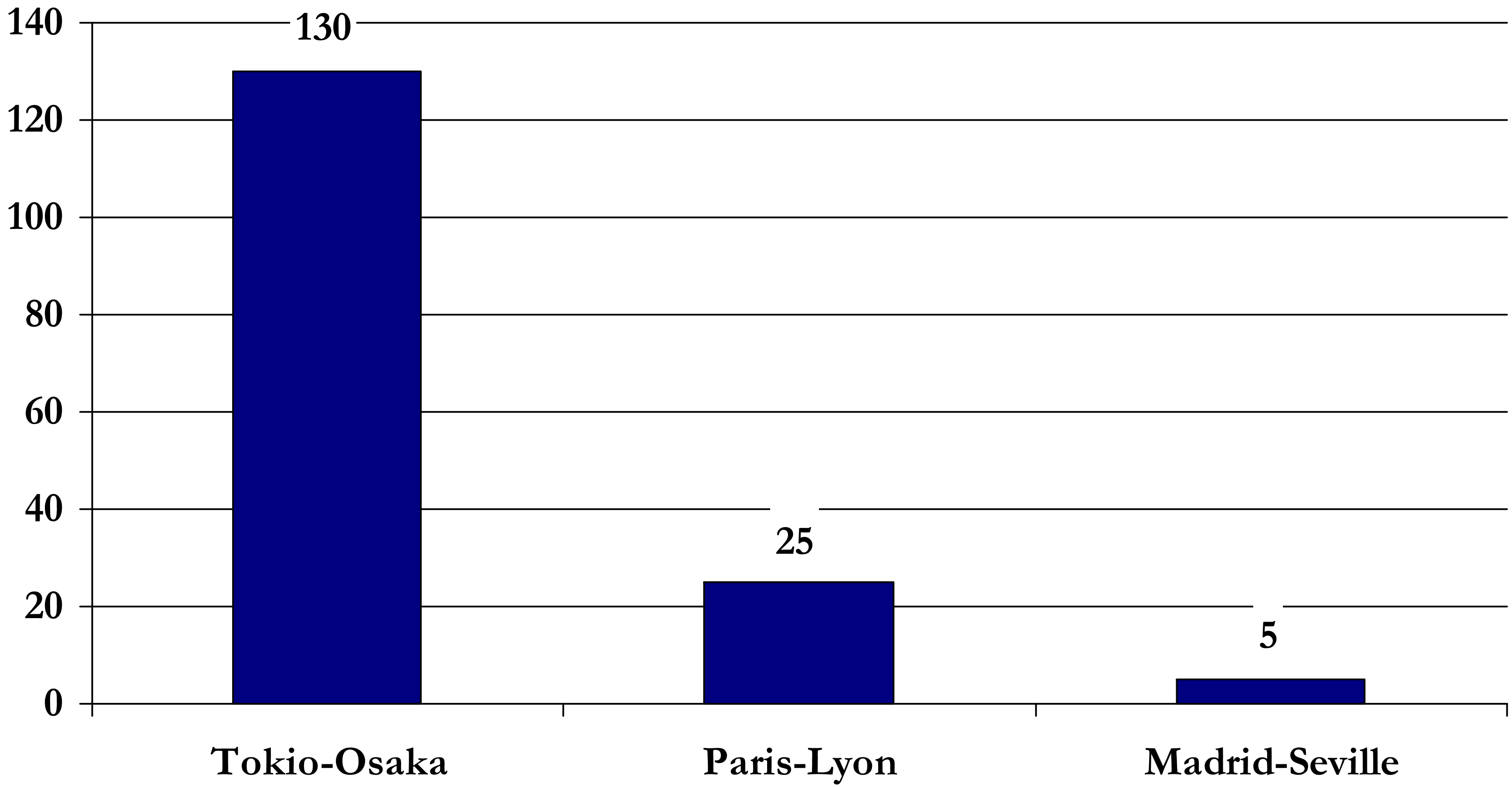
ACB de la inversión en infraestructuras

- El proyecto como *perturbación* en una economía en equilibrio

Distancia en km



Pasajeros anuales (millones)

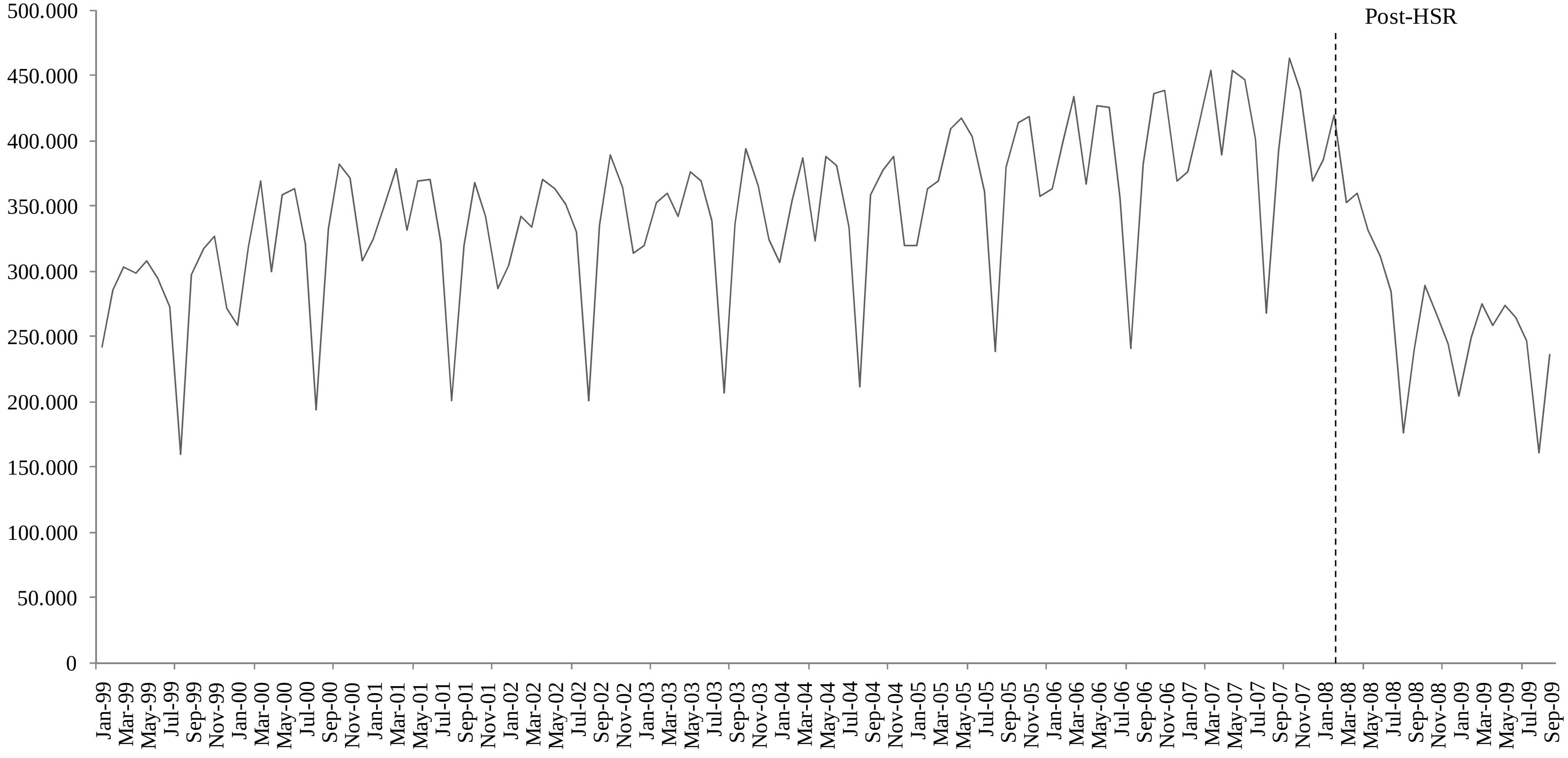


Inversión pública en alta velocidad

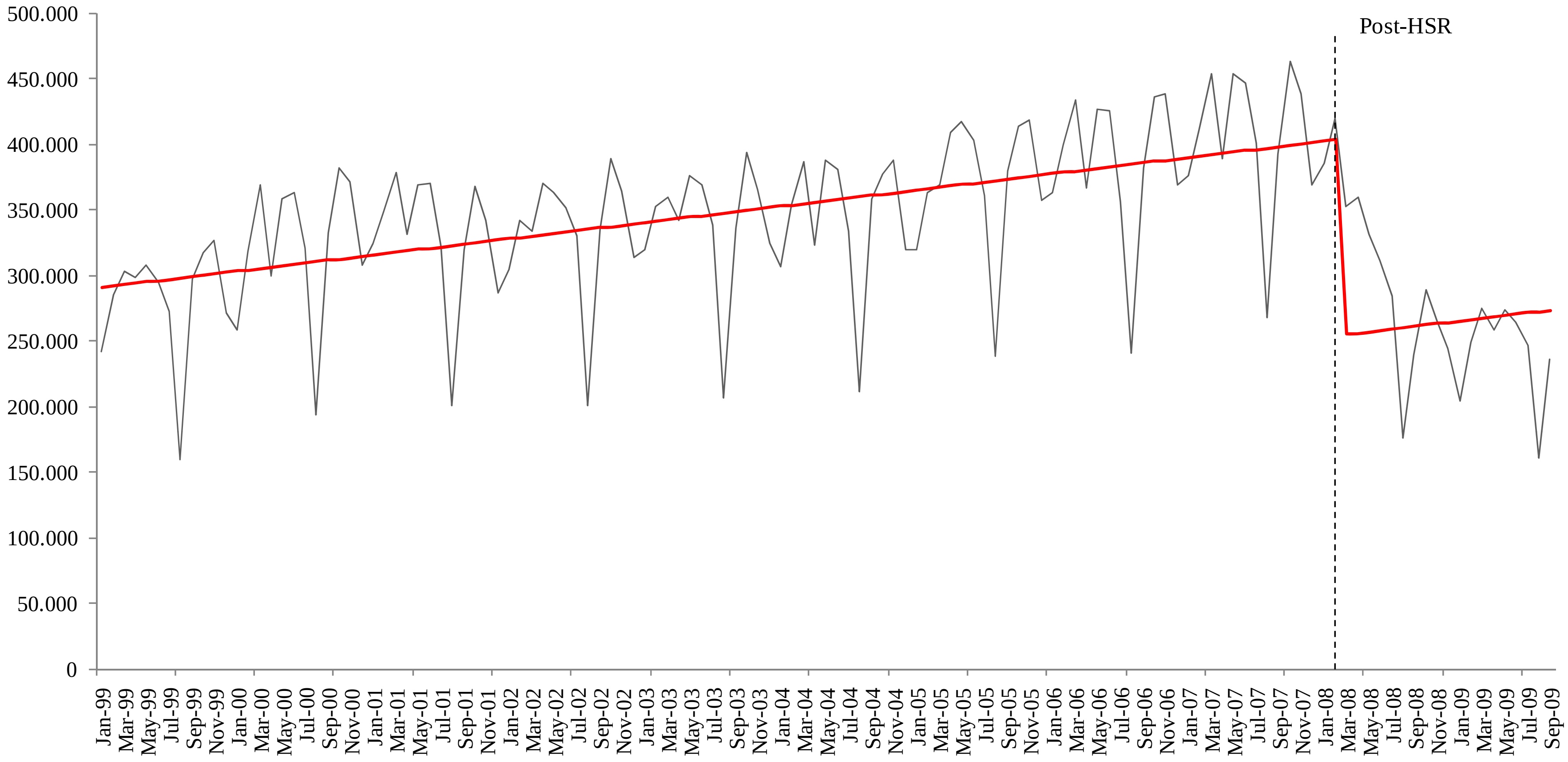
- La inversión en alta velocidad cambia el equilibrio en el corredor

Pasajeros en transporte aéreo

Madrid-Barcelona

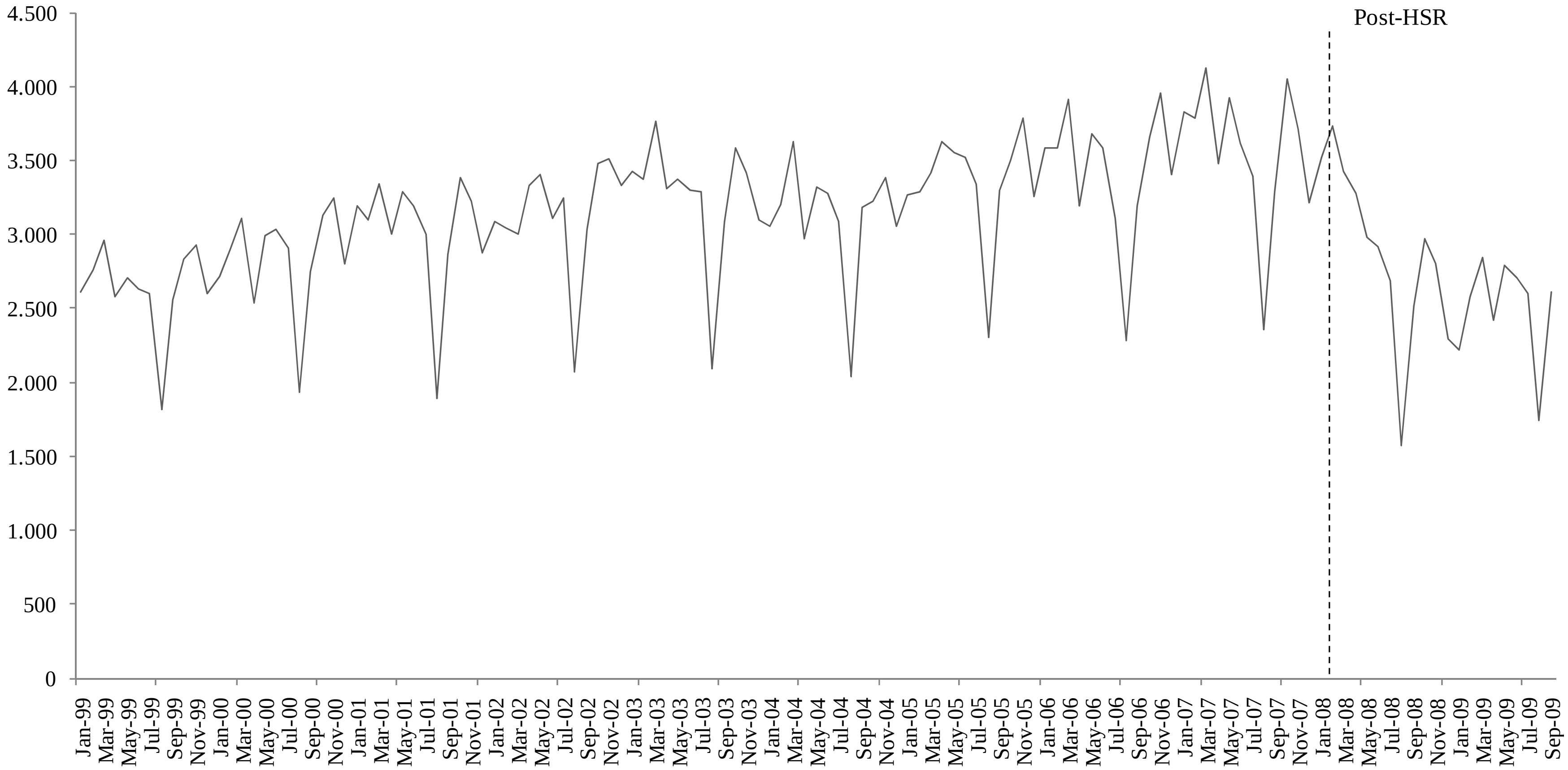


Pasajeros en transporte aéreo
Madrid-Barcelona



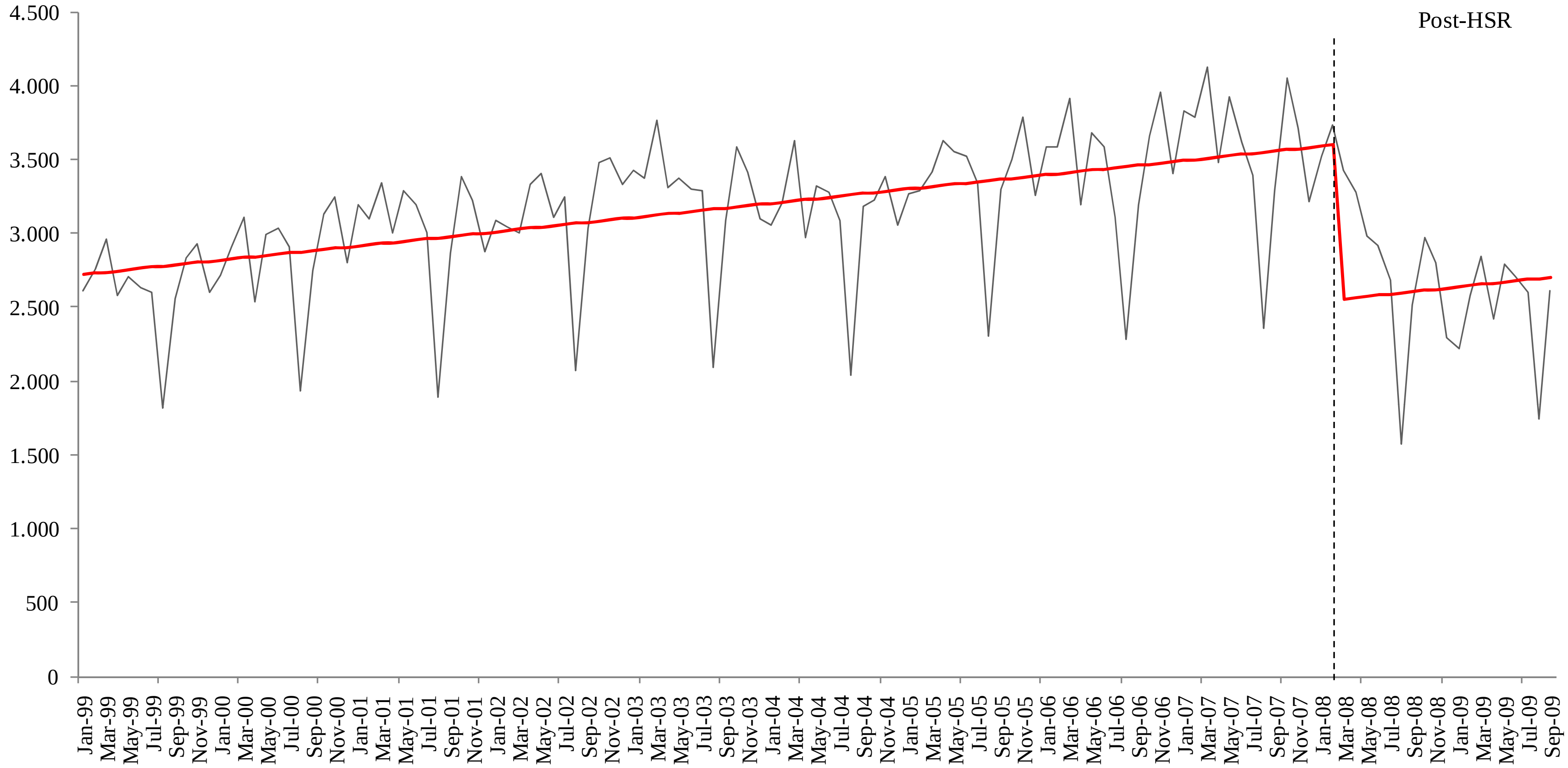
Operaciones en transporte aéreo

Madrid-Barcelona



Operaciones en transporte aéreo

Madrid-Barcelona



La competencia intermodal y la intervención del gobierno

- Las cuotas de mercado de los distintos modos de transporte dependen de los precios generalizados

- Los precios generalizados están determinados por los costes del productor y del usuario, el grado de competencia, y la política de inversión, regulación y tarificación por el uso de la infraestructura del gobierno

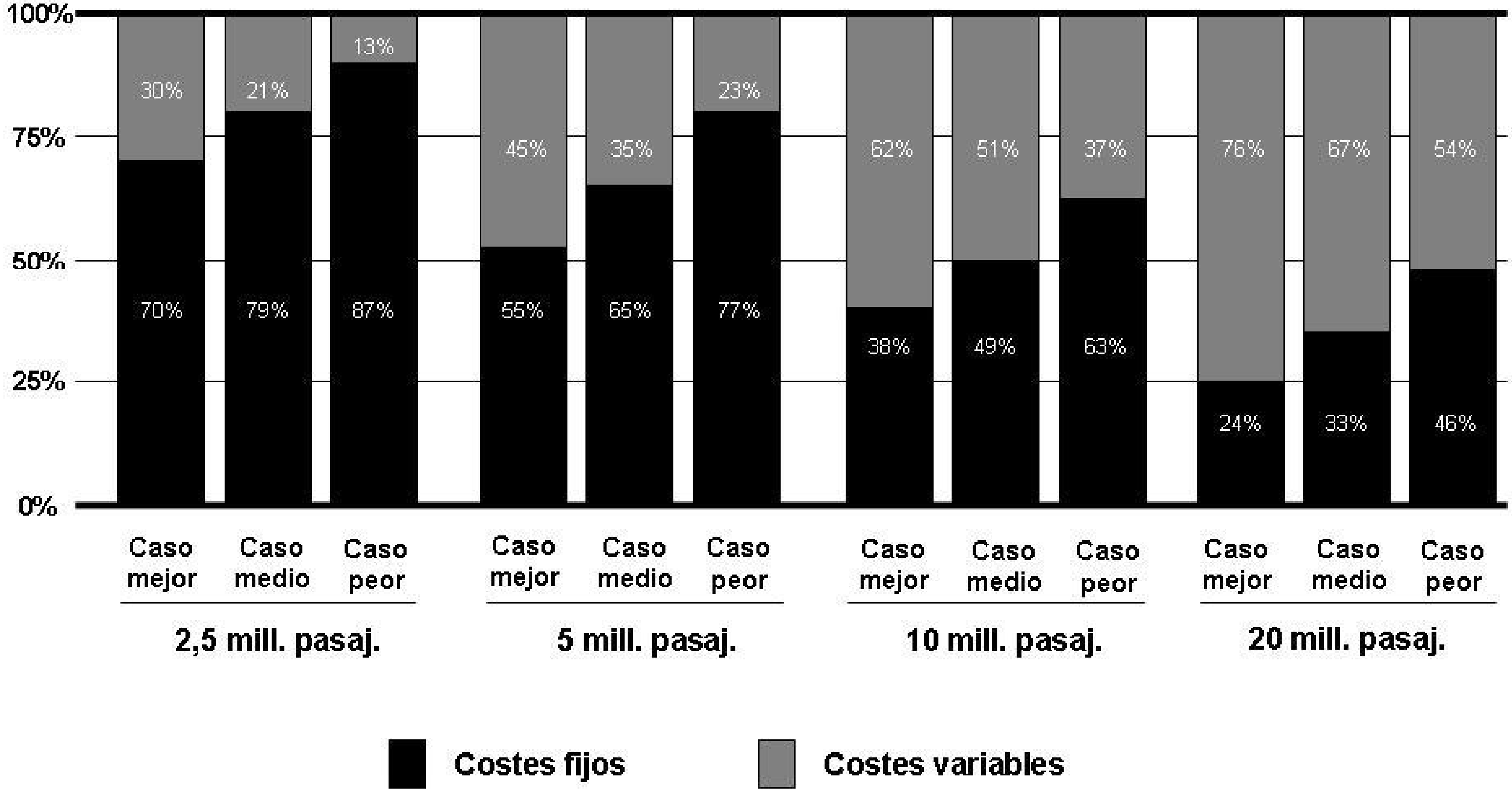
La inversión pública en alta velocidad

- La alta velocidad ferroviaria cambia el equilibrio en el mercado, afecta a la distribución modal y al bienestar social

- Política de precios y competencia intermodal:

  ¿Cada modo de transporte debe cubrir sus costes?

¿Coste marginal a corto o a largo plazo?



Más allá de las transferencias de renta…¿cómo afecta la inversión en alta velocidad al bienestar social?

High Speed Rail (HSR)

COSTS

- Infrastructure
- New rolling stock
- Maintenance of infrastructure
- Maintenance of rolling stock
- Operating costs
- Externalities
  - Land take
  - Visual intrusion
  - Noise
  - Air pollution
  - Global warming

BENEFITS

- Time savings
- Intermodal effects
  - Time savings (road, air, conventional train)
  - Externalities
  - Cost savings in alternatives modes
  - Reliability and reduction of overcrowding
  - Reduction in accidents
- Generated demand
- Wider economic benefits

The model (*without* HSR)

$$W = \int_0^T \int_{g_0}^{\infty} Q(z)e^{-rt}dzdt + \int_0^T [\overline{p}Q(g_0) - C_C(Q(g_0)]e^{-rt}dt + \sum_{i=1}^{N}\int_0^T \int_{p_{i0}}^{\infty} q_i(z)e^{-rt}dzdt$$

$$+\sum_{i=1}^{N}\int_0^T \left[p_{io}^{p} q_{i0} - C_i(q_{i0}) \right] e^{-rt}dt$$

g_0: generalised cost *without* the project.

$\overline{p}$: regulated fare.

$Q(z)$: market transport demand of users in the conventional mode.

$C_C(Q)$: total cost in the conventional mode.

q_i : level of activity in the i market.

p_{i0} : generalised price in i *without* the project.

p_{i0}^{p} : market price in i *without* the project.

T: project life.

r: social discount rate.

N: other markets in the economy.

HSR investment and operating costs

$$I + \int_0^T (C_t + C_q(Q))e^{-rt}dt$$

where:

I: infrastructure construction costs.
C_t: annual fixed maintenance and operating cost.
$C_q(Q)$: annual maintenance and operating cost variable with Q.
r: social discount rate.

The model (*with* HSR)

$$\Delta W = \int_0^T \int_{g_1}^{g_0} Q(z) e^{-rt} dz dt + \int_0^T [\bar{p}(Q_1 - Q_0) - C_t - C_q(Q_1) + C_C(Q_0)] e^{-rt} dt - I$$

$$+ \sum_{i=1}^{N} \int_0^T S_i (q_{i1} - q_{i0}) e^{-rt} dt$$

g_0: generalized cost *without* the HSR project.

g_1: generalized cost *with* the HSR project.

$\bar{p}$: regulated fare

Q_0: demand *without* the HSR project.

Q_1: demand *with* the HSR project (includes diverted and generated traffic).

C_t: annual fixed maintenance and operating cost.

$C_q(Q)$: annual maintenance and operating cost variable with Q.

$C_C(Q)$: annual avoidable cost of the conventional mode.

I: infrastructure construction costs.

N: other markets in the economy.

S_i: excess of benefits over costs of a unit change in q_i.

q_{i0}: level of activity in market i without the project.

q_{i1}: level of activity in market i with the project.

T: project life.

r: social discount rate.

Simplifying the model: Assumptions

- There are various types of indirect effects, some of them increasing the benefits of the project, other reducing them, and the final effect is negligible.
- All the alternative modes operate in competitive markets or break even in the case of regulated markets.
- Market prices are equal to opportunity costs.
- Reduction of congestion and road accidents occurs but the overall effect on the project's NPV is not significant.

Simplifying the model

NPV>0

$$\int_0^T [B(Q) - C_q(Q)] e^{-(r-\theta)t} dt \; - \int_0^T C_t e^{-rt} dt \; > I$$

B(Q): annual social benefits of the project.
$C_q(Q)$: annual maintenance and operating cost variable with Q.
C_t: annual fixed maintenance and operating cost.
I: infrastructure construction costs.
T: life of the project.
r: social discount rate.
θ : annual growth of benefits and costs which depends on Q.

Simplifying the model

$$\frac{B(Q)-C_q(Q)}{r-\theta}(1-e^{-(r-\theta)T})-\frac{C_t}{r}(1-e^{-rT})>I$$

$$\frac{B(Q)-C_q(Q)}{I}>\frac{r-\theta}{1-e^{-(r-\theta)T}}+\frac{C_t}{I}\frac{r-\theta}{r}\frac{1-e^{-rT}}{1-e^{-(r-\theta)T}}$$

First year net benefits

$$\tfrac{1}{2}(g_0 - g_1)(Q_0 + Q_1) + p_1Q_1 - p_0Q_0 - C_q + C_C$$

where:

$$[v\Delta t Q_0 + C_C](1+\alpha) - C_q$$

g_0 : generalized cost *without* HSR.

g_0 : generalized cost *with* HSR.

Q_0: demand *without* HSR.

Q_1: demand *with* the HSR project.

C_q: annual maintenance and operating cost variable with Q.

C_C: annual variable cost of the conventional mode.

v: average value of time.

Δt : average time saving.

α : growth rate of generated traffic *with* the project.

First year Q (deviated) for NPV>0

$$Q_0 > \frac{1}{v\Delta t(1+\alpha)}\left[\frac{r-\theta}{1-e^{-(r-\theta)T}} I + C_q + C_t \frac{r-\theta}{r}\frac{1-e^{-rT}}{1-e^{-(r-\theta)T}} - C_C(1+\alpha)\right]$$

HSR costs

Table 1. Estimated costs of a 500 km HSR line in Europe (2004)

	Cost per unit (€ thousand)	*Units*	*Total cost (€ million)*
Infrastructure construction[(1)] (Km.)	12,000-40,000	500	6,000-20,000
Infrastructure maintenance (Km.)	65	500	32.5
Rolling stock[(2)] (Trains)	15,000	40	600.0
Rolling stock maintenance (Trains)	900	40	36.0
Energy (Trains)	892	40	35.7
Labour (Employees)	36	550	19.8

Source: UIC

[(1)] Terminal value = 50% of the investment in infrastructure.
[(2)] NPV of rolling stock investment = 20% of the investment in infrastructure.

Value of time

Passenger transport: VOT per person/hour

Relevant VOT studies Transport Segment	HCG 1994	HCG 1998 Euro 1998	SNRA 1997	EUNET 1998	UNITE Values Euro 1998
Car / motorcycle		6.70	9.31		
Business	21.23	21.00	11.95		21.00
Commuting / private	5.53	6.37	3.91		6.00
Leisure / holiday	3.79	5.08	3.10		4.00
Coach (inter-urban)					
Business	21.23				21.00
Commuting / private	5.95		5.40		6.00
Leisure / holiday	3.08		4.37		4.00
Urban bus / tramway					
Business	21.23				21.00
Commuting / private	5.95		4.94		6.00
Leisure / holiday	3.08		3.22		3.20
Inter-urban rail		4.97	8.50		
Business		18.43	11.95		21.00
Commuting / private		6.48	6.21		6.40
Leisure / holiday		4.41	4.94		4.70
Air traffic				40.60	
Business			16.20		28.50
Commuting / private			10.11		10.00
Leisure / holiday			10.11		10.00

Table 4.7 Estimated VTTS values – work (business) passenger trips (2002 Euros per passenger per hour, factor prices)

Country	Business		
	Air	Bus	Car, train
Austria	39.11	22.79	28.40
Belgium	37.79	22.03	27.44
Cyprus	29.04	16.92	21.08
Czech Republic	19.65	11.45	14.27
Denmark	43.43	25.31	31.54
Estonia	17.66	10.30	12.82
Finland	38.77	22.59	28.15
France	38.14	22.23	27.70
Germany	38.37	22.35	27.86
Greece	26.74	15.59	19.42
Hungary	18.62	10.85	13.52
Ireland	41.14	23.97	29.87
Italy	35.29	20.57	25.63
Latvia	16.15	9.41	11.73
Lithuania	15.95	9.29	11.58
Luxembourg	52.36	30.51	38.02
Malta	25.67	14.96	18.64
Netherlands	38.56	22.47	28.00
Poland	17.72	10.33	12.87
Portugal	26.63	15.52	19.34
Slovakia	17.02	9.92	12.36
Slovenia	25.88	15.08	18.80
Spain	30.77	17.93	22.34
Sweden	41.72	24.32	30.30
United Kingdom	39.97	23.29	29.02
EU (25 Countries)	**32.80**	**19.11**	**23.82**
Switzerland	45.41	26.47	32.97

Table 4.8 Estimated VTTS values – non-work passenger trips (2002 Euros per passenger per hour, factor prices)

Country	Commute-Short Distance			Commute-Long Distance			Other-Short Distance			Other-Long Distance		
	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train
Austria	11.98	5.78	8.03	15.40	7.42	10.32	10.05	4.84	6.73	12.91	6.22	8.65
Belgium	11.44	5.51	7.67	14.68	7.07	9.84	9.59	4.62	6.43	12.31	5.93	8.26
Cyprus	11.83	5.70	7.93	15.18	7.32	10.18	9.92	4.78	6.65	12.74	6.14	8.53
Czech Republic	8.57	4.13	5.75	11.00	5.31	7.38	7.19	3.46	4.82	9.23	4.45	6.18
Denmark	12.64	6.09	8.48	16.23	7.82	10.88	10.60	5.11	7.11	13.61	6.56	9.12
Estonia	7.44	3.58	4.99	9.55	4.60	6.40	6.24	3.01	4.18	8.01	3.86	5.36
Finland	11.31	5.45	7.58	14.52	7.00	9.73	9.48	4.57	6.36	12.17	5.87	8.16
France	16.34	7.87	10.95	20.97	10.11	14.06	13.70	6.60	9.18	17.58	8.47	11.79
Germany	11.99	5.78	8.04	15.40	7.42	10.32	10.05	4.85	6.74	12.91	6.22	8.65
Greece	10.34	4.98	6.93	13.28	6.40	8.90	8.67	4.18	5.82	11.14	5.37	7.46
Hungary	7.53	3.63	5.05	9.68	4.66	6.48	6.31	3.04	4.23	8.11	3.91	5.44
Ireland	12.51	6.03	8.39	16.07	7.74	10.77	10.49	5.06	7.04	13.48	6.49	9.03
Italy	15.16	7.31	10.16	19.47	9.38	13.04	12.71	6.12	8.52	16.32	7.86	10.94
Latvia	6.79	3.27	4.55	8.72	4.20	5.85	5.69	2.74	3.82	7.31	3.52	4.90
Lithuania	6.62	3.19	4.43	8.49	4.09	5.69	5.55	2.67	3.72	7.12	3.43	4.77
Luxembourg	17.77	8.60	11.91	22.82	11.00	15.30	14.90	7.18	9.99	19.13	9.22	12.83
Malta	9.73	4.69	6.53	12.50	6.02	8.37	8.17	3.93	5.47	10.48	5.05	7.02
Netherlands	11.59	5.59	7.77	14.88	7.17	9.97	9.72	4.68	6.52	12.48	6.01	8.37
Poland	7.36	3.55	4.94	9.46	4.56	6.34	6.17	2.97	4.14	7.93	3.82	5.32
Portugal	9.97	4.81	6.69	12.81	6.18	8.59	8.36	4.03	5.61	10.74	5.17	7.20
Slovakia	6.87	3.31	4.60	8.82	4.25	5.91	5.76	2.78	3.86	7.40	3.57	4.96
Slovenia	12.00	5.78	8.04	15.40	7.42	10.33	10.06	4.85	6.74	12.92	6.22	8.66
Spain	12.72	6.12	8.52	16.33	7.87	10.94	10.66	5.13	7.15	13.69	6.59	9.18
Sweden	12.24	5.90	8.20	15.71	7.57	10.53	10.26	4.94	6.88	13.17	6.35	8.83
United Kingdom	12.44	5.99	8.34	15.97	7.69	10.70	10.43	5.02	6.99	13.39	6.46	8.98
EU (25 Countries)	**12.65**	**6.10**	**8.48**	**16.25**	**7.83**	**10.89**	**10.61**	**5.11**	**7.11**	**13.62**	**6.56**	**9.13**
Switzerland	16.74	8.06	11.22	21.49	10.36	14.41	14.03	6.76	9.40	18.02	8.69	12.08

Expected average time saving per passenger

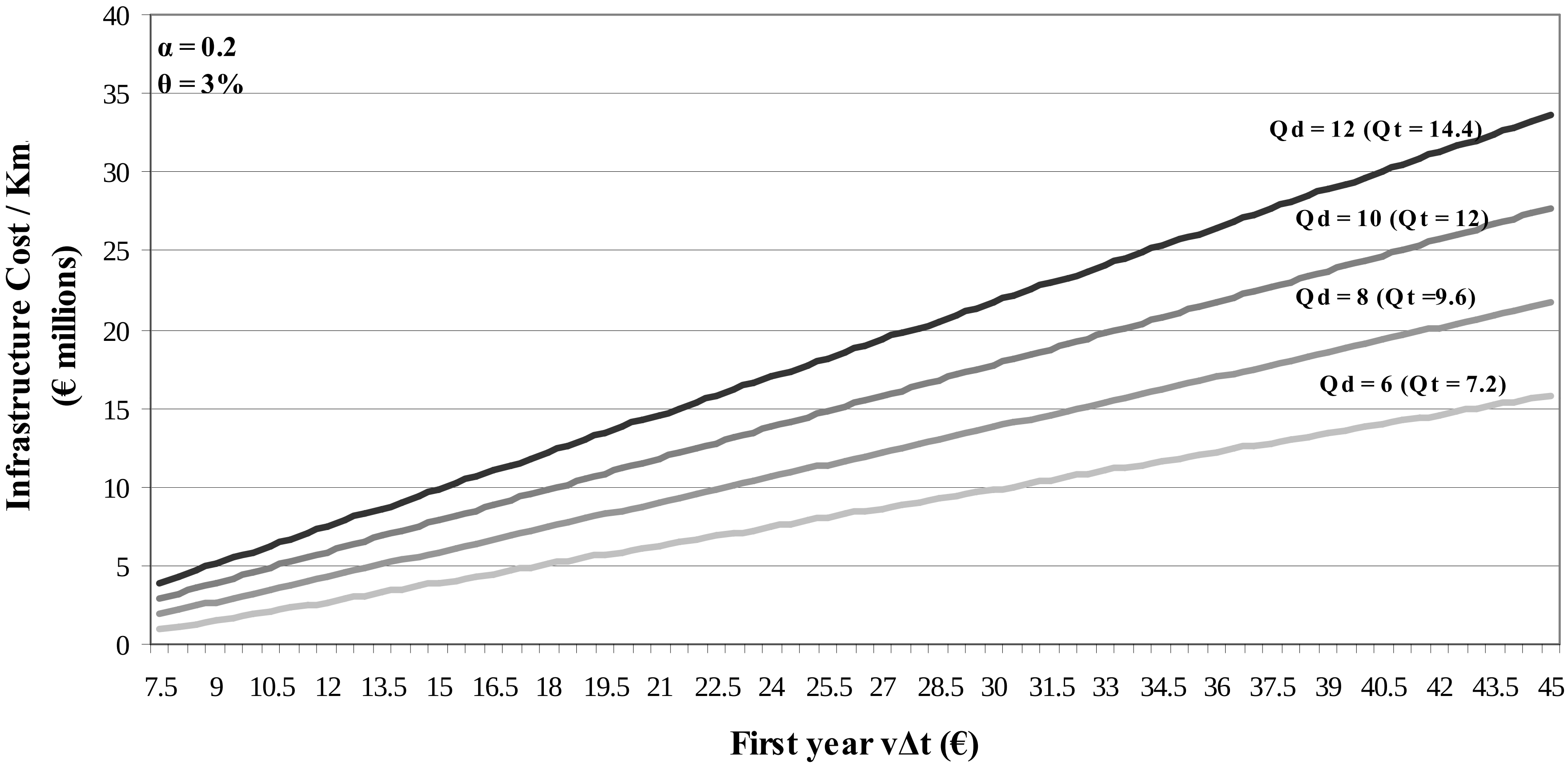
- For distances in the range of 350-400 km, and the conventional rail service with an operating speed of 130 km/h (representative of many main lines in Europe), a typical HSR yields 45-50 minutes savings
- When conventional trains run at 100 km/h, potential time savings are one hour or more
- If the conventional train's operating speed is 160 km/hr, time saving is 35 minutes over a distance of 450 km
- These average values imply that all passengers travel the whole length of the line

Expected average time saving per passenger

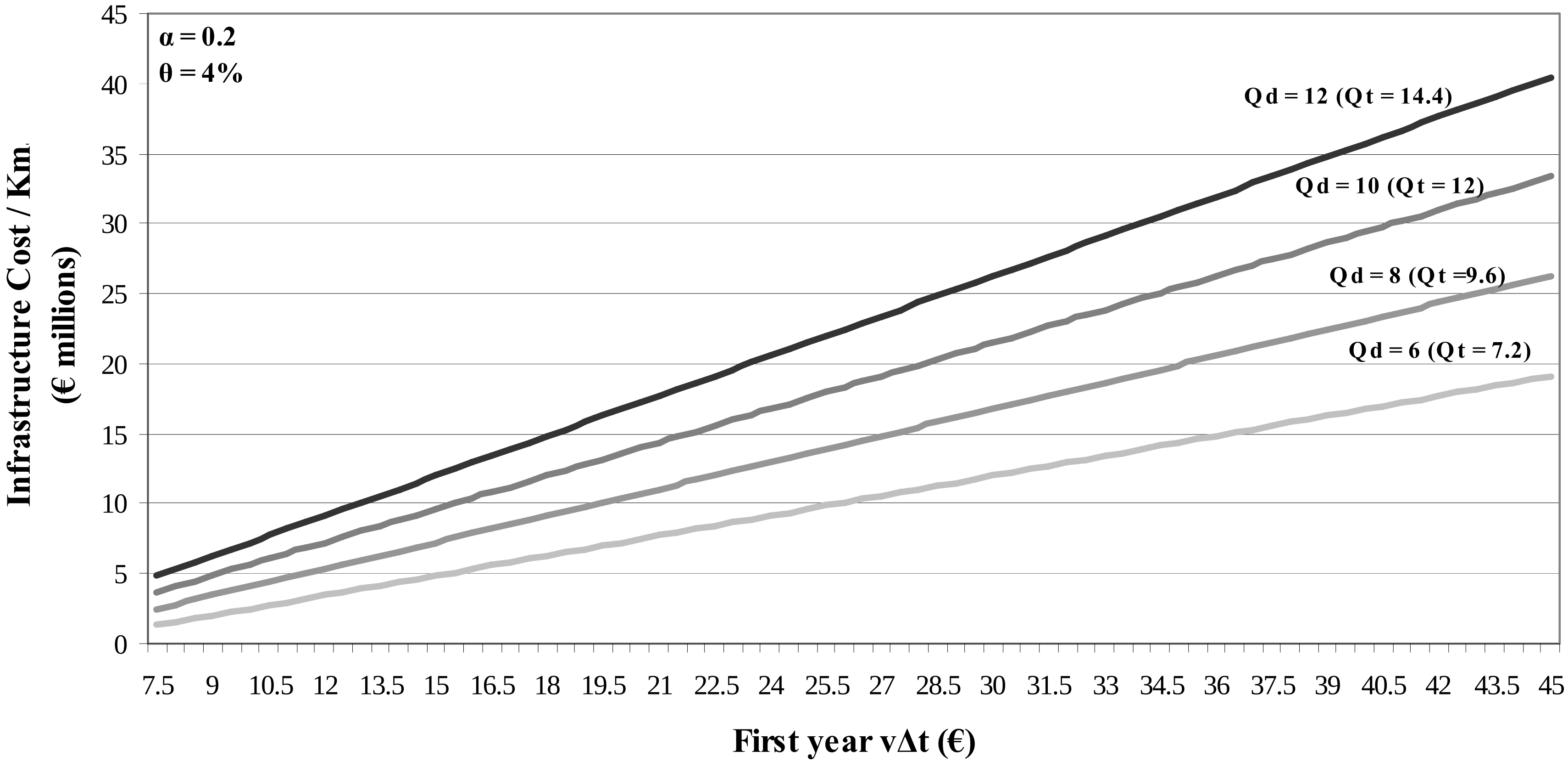
- Diverted traffic comes also from road and air transport. Time savings are lower when passengers divert from air transport, though higher when passengers shift from road transport

- In this paper we assume that the average time saving per passenger goes from half an hour to an hour and a half, which probably includes any potential case in Europe

First year demand for NPV=0



First year demand for NPV=0

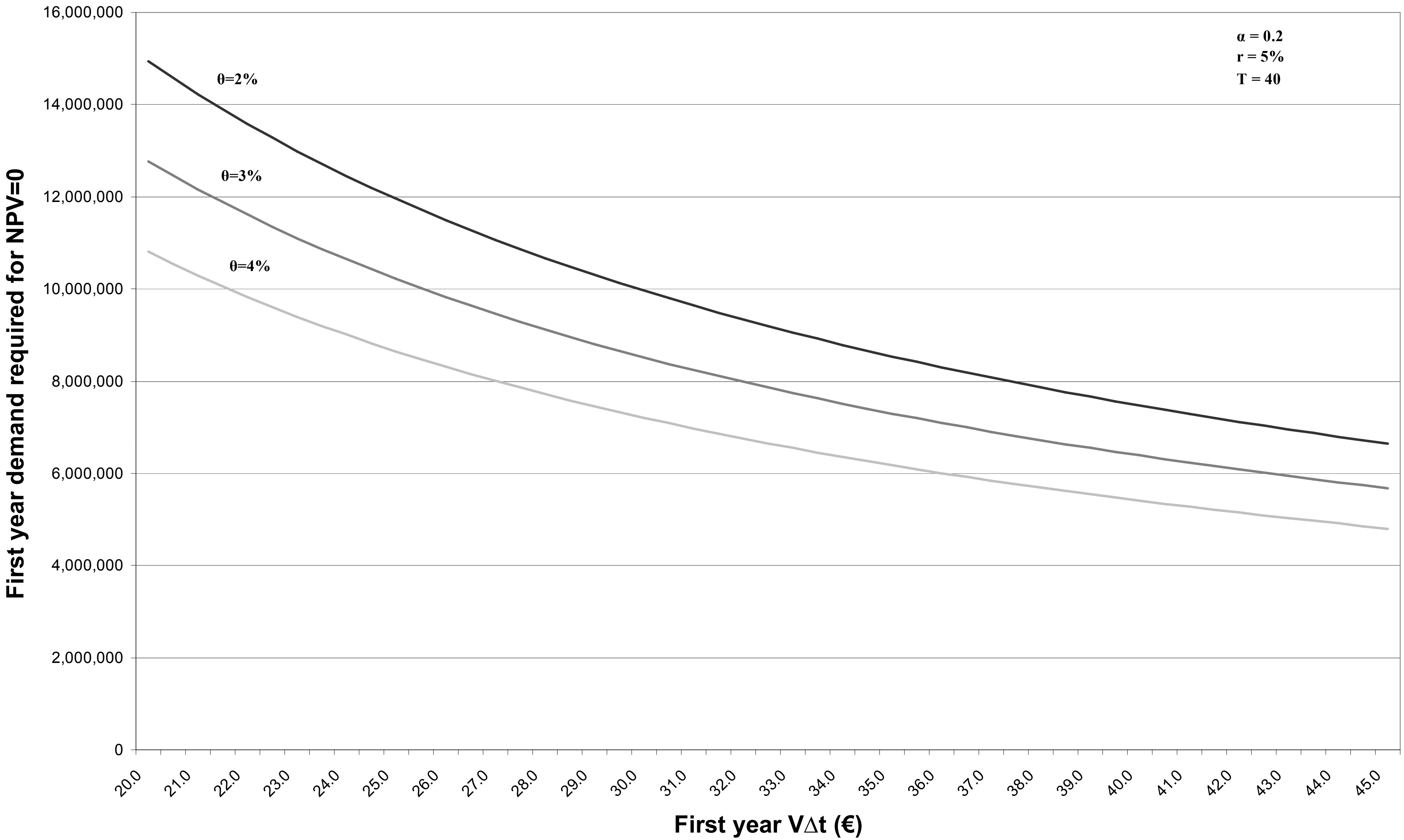


First year demand required for NPV=0

(r=5% α=0.2 T=40)

Investment costs per km: €12M

(Construction costs + NPV of rolling stock)

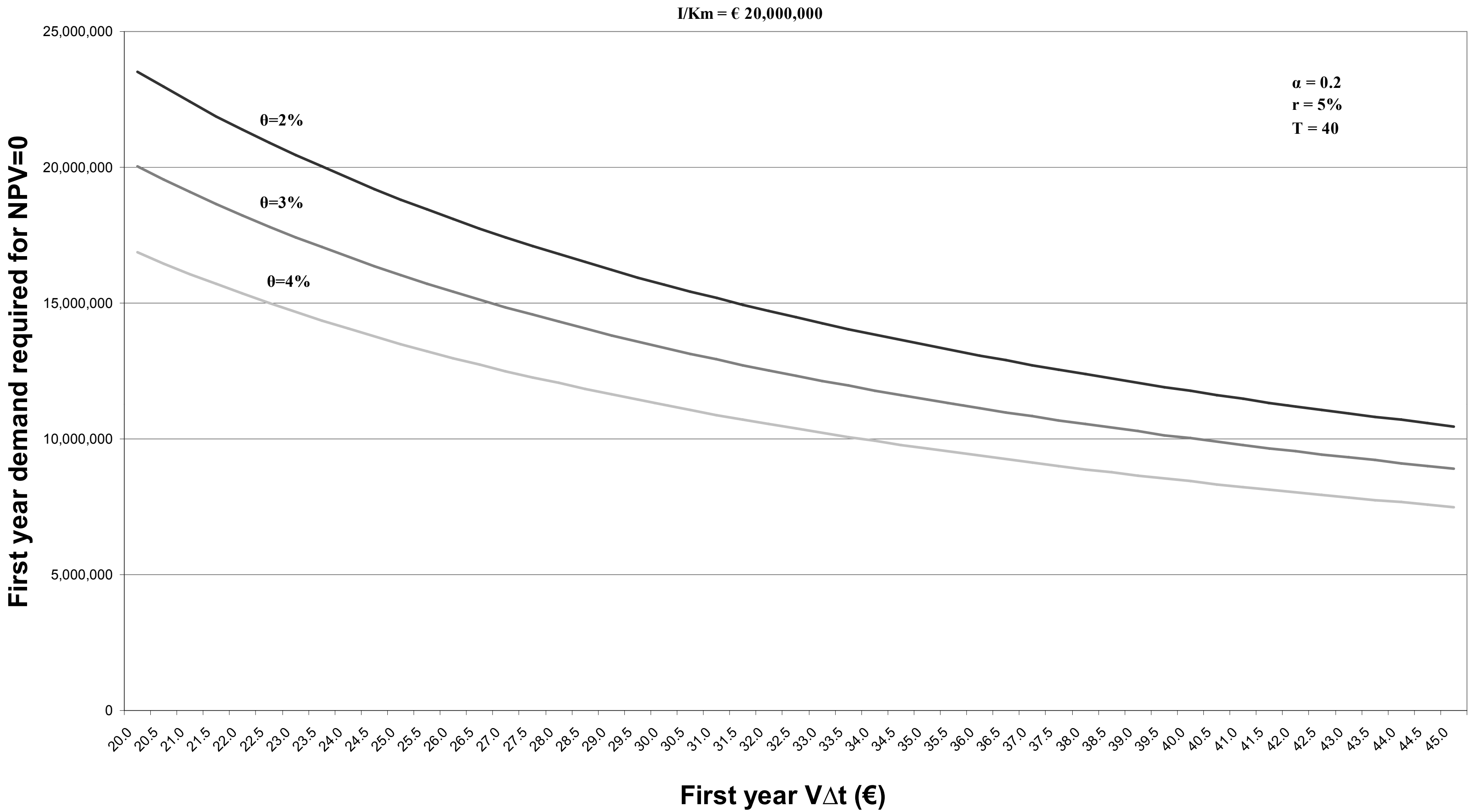


First year demand required for NPV=0

(r=5% α=0.2 T=40)

Investment costs per km: €20M

(Construction costs + NPV of rolling stock)

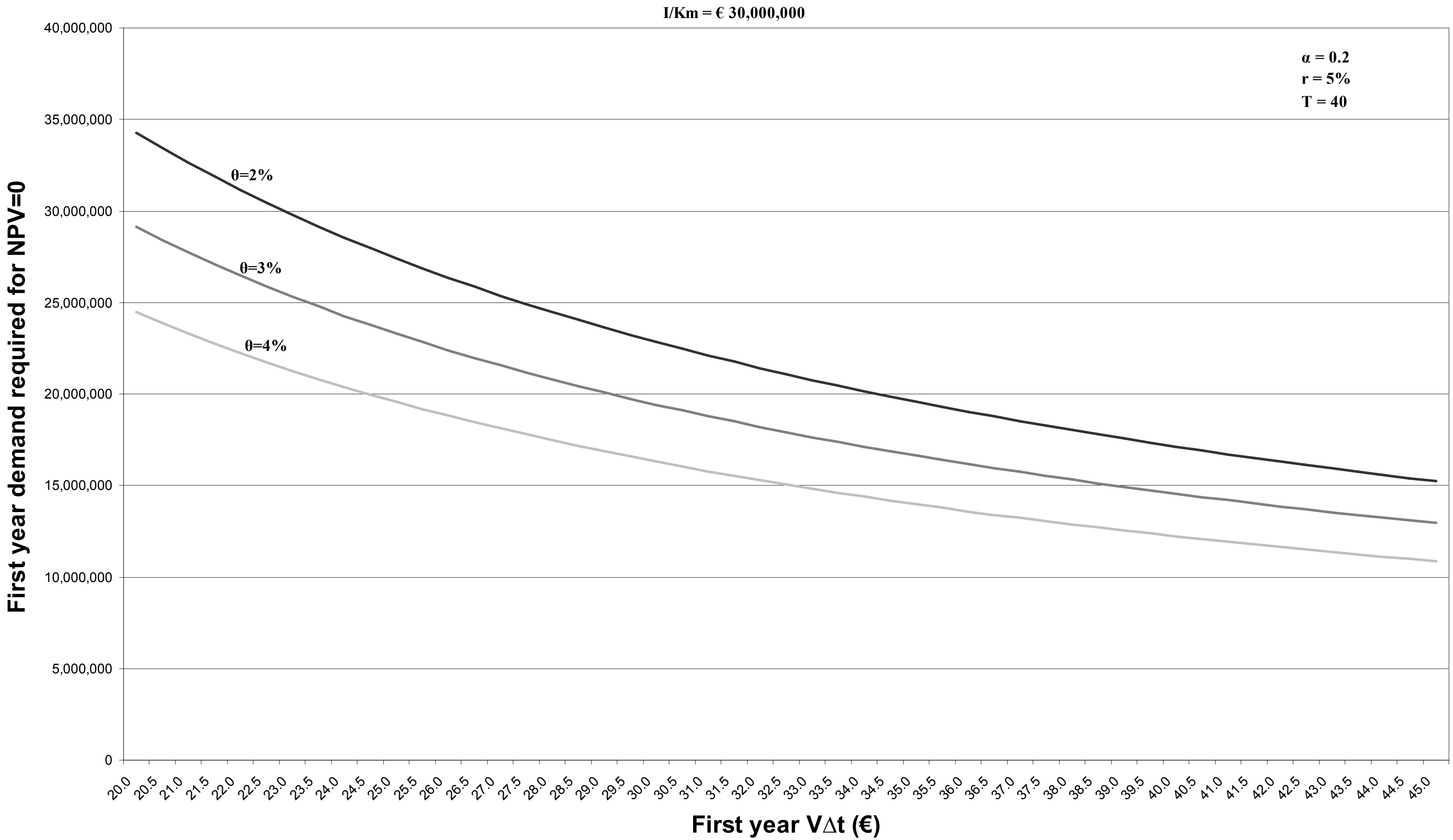


First year demand required for NPV=0

(r=5% α=0.2 T=40)

Investment costs per km: €30M

(Construction costs + NPV of rolling stock)



First year demand thresholds for NPV=0

(r=5% T=40 Ct=32.5 Cq=91.5 Cc=62)

		Q_t											
		α											
		20%			30%			40%			50%		
		θ											
I	vΔt	2%	3%	4%	2%	3%	4%	2%	3%	4%	2%	3%	4%
12	20	14.9	12.8	10.8	14.6	12.5	10.5	14.3	12.2	10.2	14.0	11.8	9.9
12	30	10.0	8.5	7.2	9.8	8.3	7.0	9.5	8.1	6.8	9.3	7.9	6.6
12	45	6.6	5.7	4.8	6.5	5.5	4.7	6.4	5.4	4.5	6.2	5.3	4.4
20	20	23.5	20.0	16.9	23.2	19.7	16.6	22.9	19.4	16.3	22.6	19.1	15.9
20	30	15.7	13.4	11.2	15.5	13.2	11.0	15.3	12.9	10.8	15.1	12.7	10.6
20	45	10.5	8.9	7.5	10.3	8.8	7.4	10.2	8.6	7.2	10.0	8.5	7.1
30	20	34.3	29.1	24.5	33.9	28.8	24.1	33.6	28.5	23.8	33.3	28.2	23.5
30	30	22.8	19.4	16.3	22.6	19.2	16.1	22.4	19.0	15.9	22.2	18.8	15.7
30	45	15.2	12.9	10.9	15.1	12.8	10.7	15.0	12.7	10.6	14.8	12.5	10.5
40	20	45.0	38.2	32.0	44.7	37.9	31.7	44.4	37.6	31.4	44.1	37.3	31.1
40	30	30.0	25.5	21.4	29.8	25.3	21.2	29.6	25.0	20.9	29.4	24.8	20.7
40	45	20.0	17.0	14.2	19.9	16.8	14.1	19.7	16.7	14.0	19.6	16.6	13.8

First year demand thresholds for NPV=0

(r=3% T=40 Ct=32.5 Cq=91.5 Cc=62)

				Q_t											
				α											
				20%			30%			40%			50%		
				θ											
				2%	3%	4%	2%	3%	4%	2%	3%	4%	2%	3%	4%
I	12	vΔt	20	11.1	10.0	7.7	10.8	9.7	7.4	10.5	9.4	7.1	10.2	9.1	6.8
			30	7.4	6.7	5.1	7.2	6.4	4.9	7.0	6.2	4.7	6.8	6.0	4.5
			45	4.9	4.4	3.4	4.8	4.3	3.3	4.7	4.2	3.2	4.5	4.0	3.0
	20		20	17.2	15.0	11.8	16.9	14.7	11.5	16.5	14.4	11.2	16.2	14.1	10.9
			30	11.4	10.0	7.9	11.2	9.8	7.7	11.0	9.6	7.4	10.8	9.4	7.2
			45	7.6	6.7	5.2	7.5	6.5	5.1	7.4	6.4	5.0	7.2	6.2	4.8
	30		20	24.8	21.2	16.9	24.4	20.9	16.6	24.1	20.6	16.3	23.8	20.3	15.9
			30	16.5	14.2	11.2	16.3	13.9	11.0	16.1	13.7	10.8	15.9	13.5	10.6
			45	11.0	9.4	7.5	10.9	9.3	7.4	10.7	9.2	7.2	10.6	9.0	7.1
	40		20	32.3	27.5	22.0	32.0	27.2	21.6	31.7	26.9	21.3	31.4	26.6	21.0
			30	21.6	18.3	14.6	21.4	18.1	14.4	21.1	17.9	14.2	20.9	17.7	14.0
			45	14.4	12.2	9.8	14.2	12.1	9.6	14.1	11.9	9.5	14.0	11.8	9.3

Dos observaciones

- El caso base debe ser un *do minimum* y otras alternativas (*do something* options) deberían ser examinadas

- Umbrales de demanda y tarificación (marginal cost pricing and intermodal competition)

Conclusiones

- La rentabilidad social de invertir en HSR requiere un flujo de demanda elevado con suficiente aportación de valor para compensar los altos costes de proveer capacidad

- No es sólo que el volumen de viajeros sea alto, se requiere una alta disposición a pagar

- Cuando los beneficios adicionales como la reducción de congestión y accidentes, y otros efectos indirectos no son significativos es difícil justificar la inversión en HSR si la demanda esperada en el primer año es inferior a 10 millones de viajeros

Referencias

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