Productivity benefits of urban transportation megaprojects:
a general equilibrium analysis of «Projet du Grand Paris»

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How we model the Paris metropolitan region?

We use the

R*egional* ***E****conomy* ***L****and* ***U****se-****TRAN****sportation*

Computable General Equilibrium model
(A multi-equation structural model unburdened by
econometric restrictions, calibrated but capable
of dealing with a variety of parameter values)

The Paris version of RELU-TRAN
Complete description in Appendix of this paper
Earlier published articles:

https://sites.google.com/site/alexanashomepage/the-relu-tran-model-and-its-applications

Polycentric urban model: jobs and population are endogenously determined
and appear anywhere in the region

Consumers choose:

1) resident location,

2) workplace,

3) housing type & size,

4) labor supply,

5) non-work trips and work trips,

6) mode choice and route of travel for each trip

Firms choose: input combinations, purchases from each other,
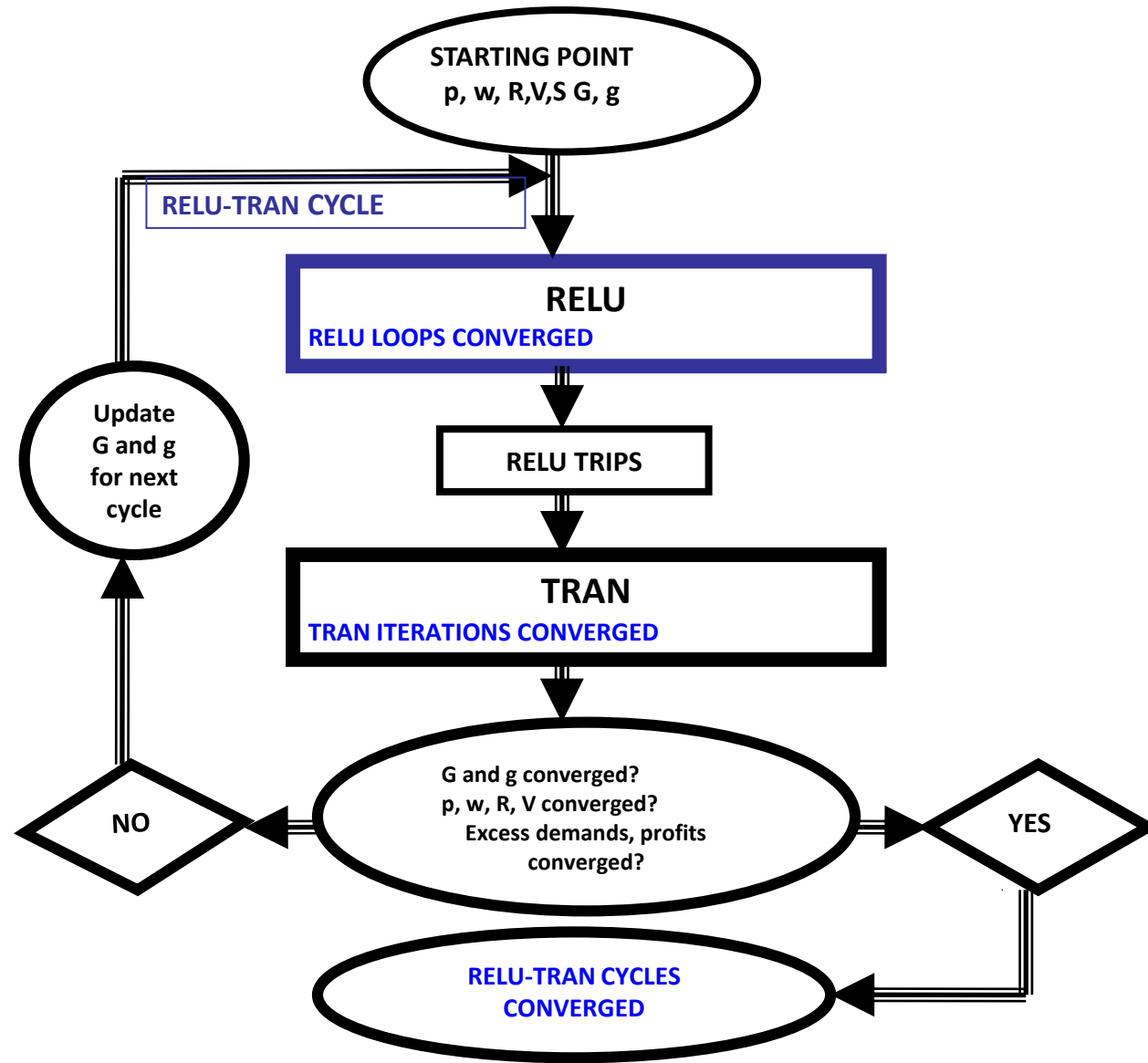export/import, output level, CRTS, make zero profit

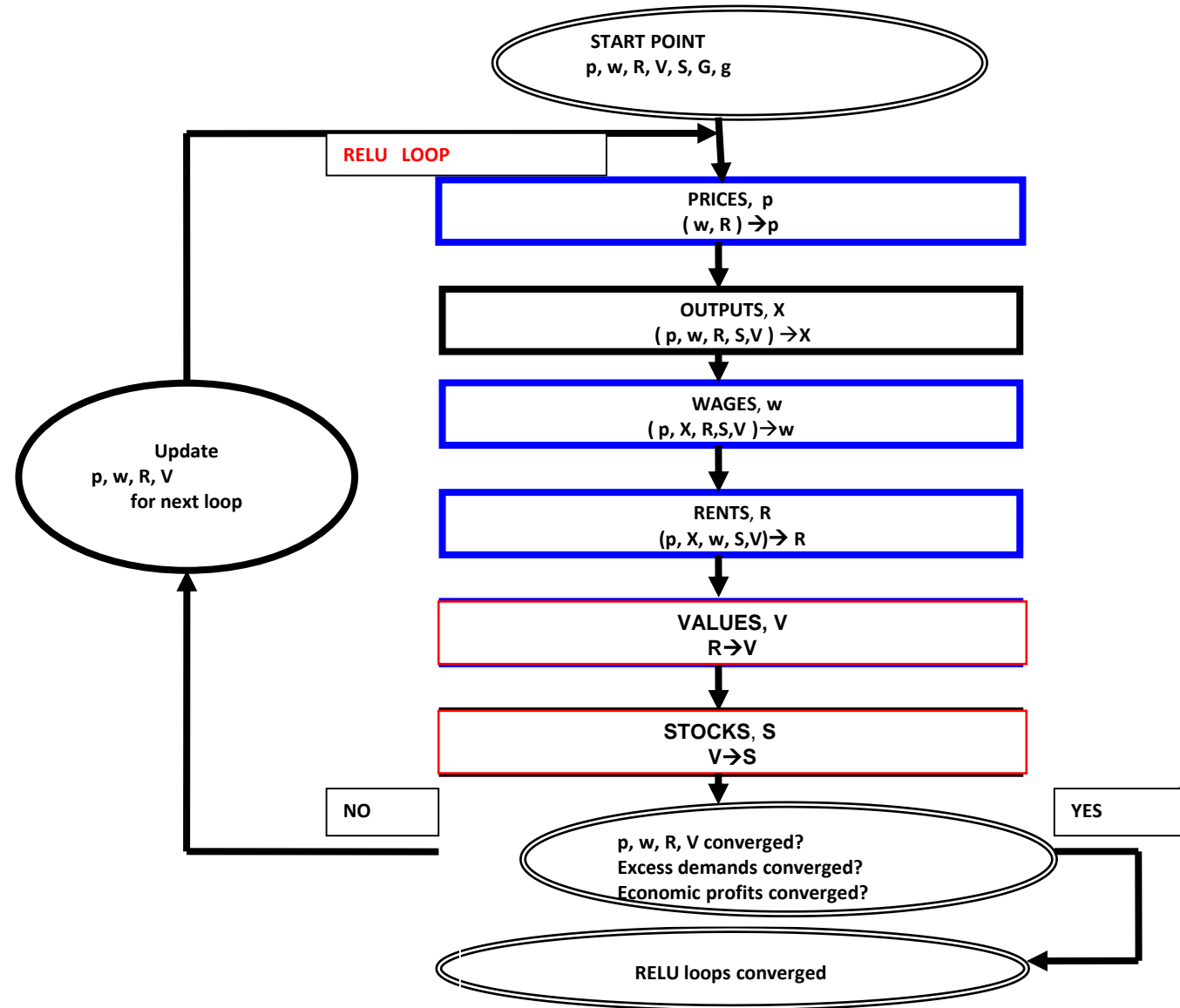**Developers:**   Build and demolish buildings of different types

Government: Collects taxes, sets congestion tolls, etc.
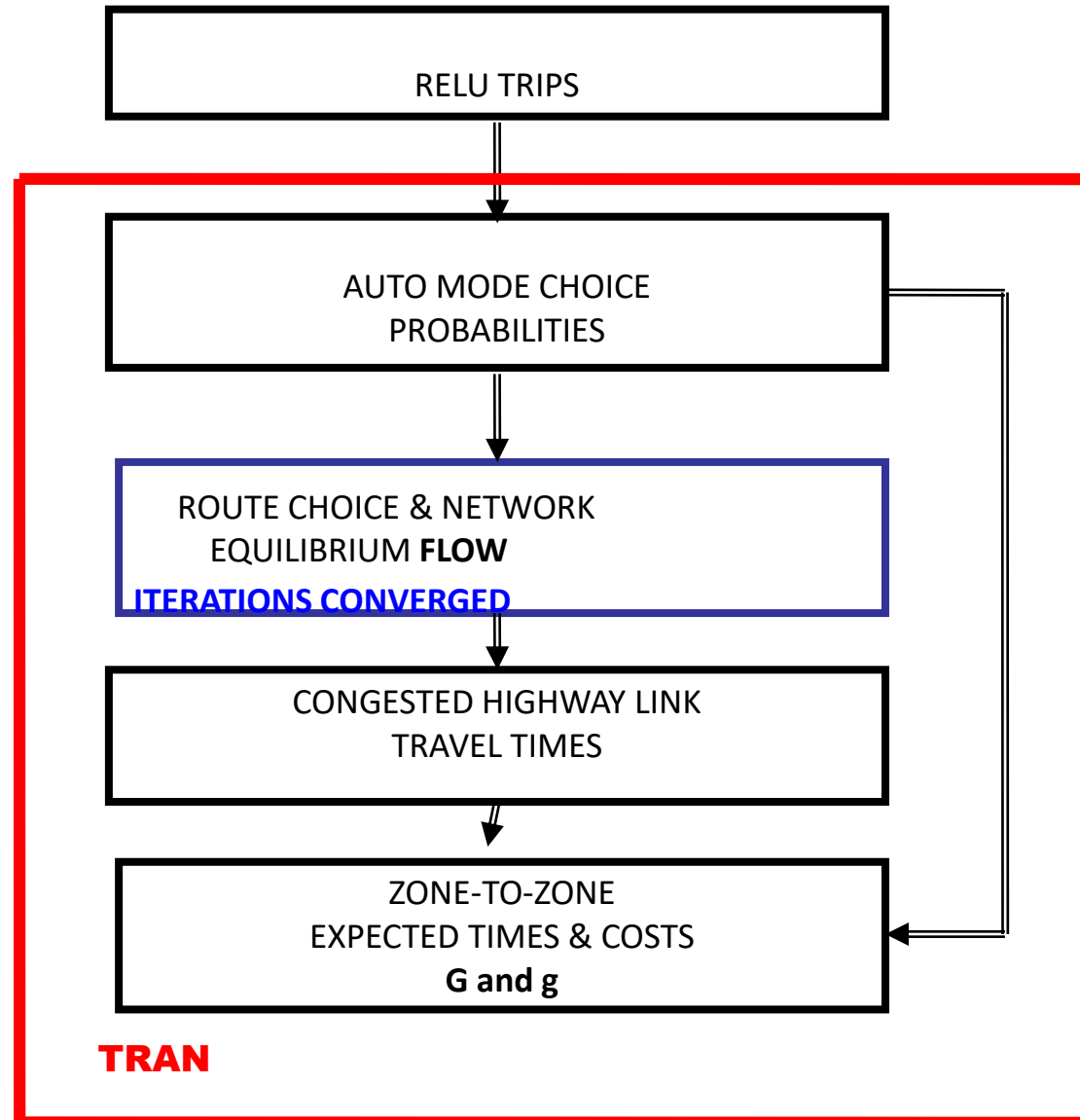
RELU-TRAN MODEL FLOWCHART (Anas and Liu, 2007)

The RELU algorithm

The TRAN Algorithm

Zone definitions in the Paris RELU-TRAN model

Dark pink (CDTs, Poles)

Light pink: Non-CDT inner suburbs

City of Paris

Yellow: Outer suburbs

Id	Name of pole
22	La Défense
25	Biotechnologies Seine-Amont
28	Descartes
30	Aulnay-Montfermeil
31	Roissy pôle
32	Le Bourget
33	Gonnesse Val-de-France
34	Pleyel
38	Confluence
42	Saclay
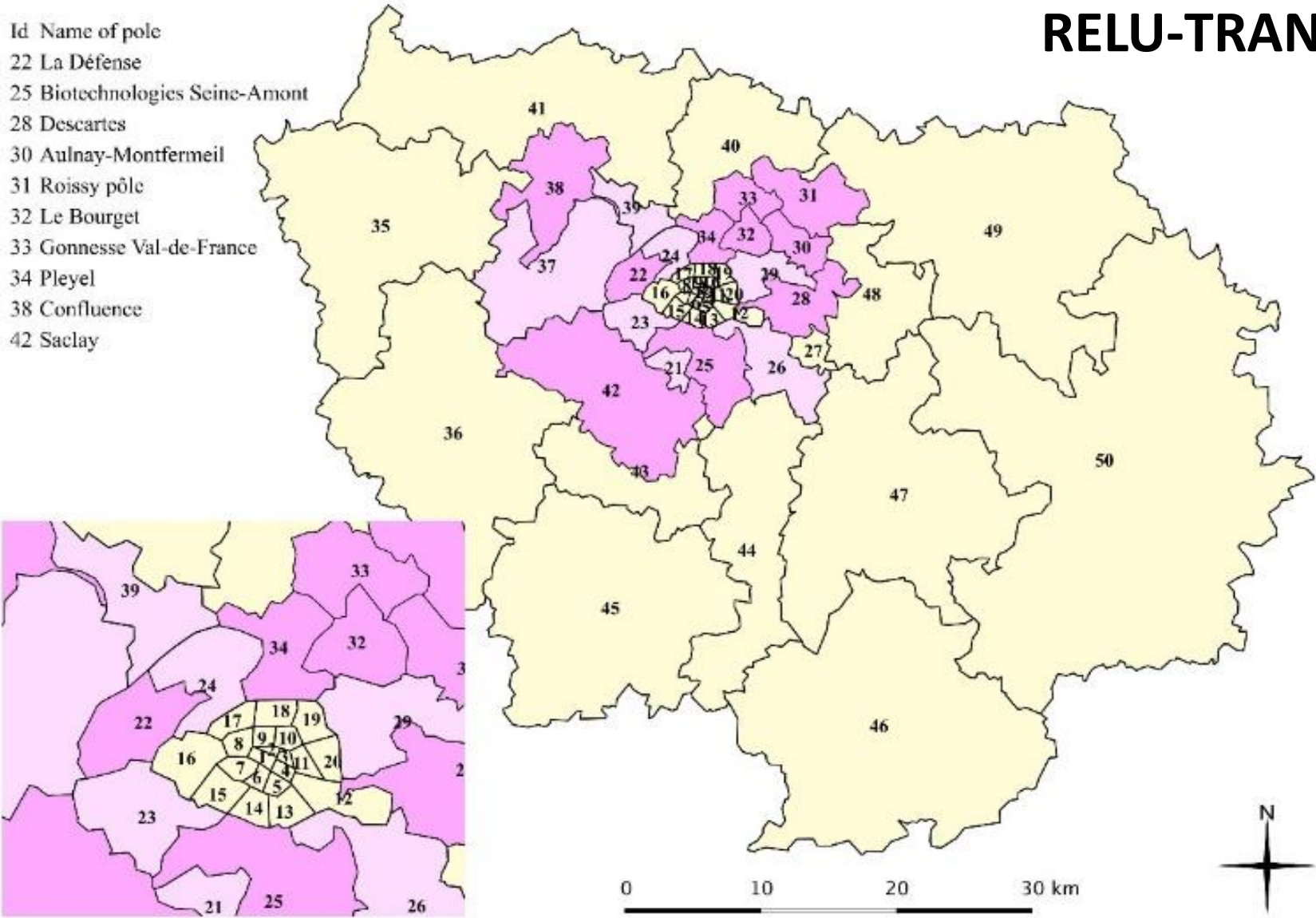
The PGP megaproject
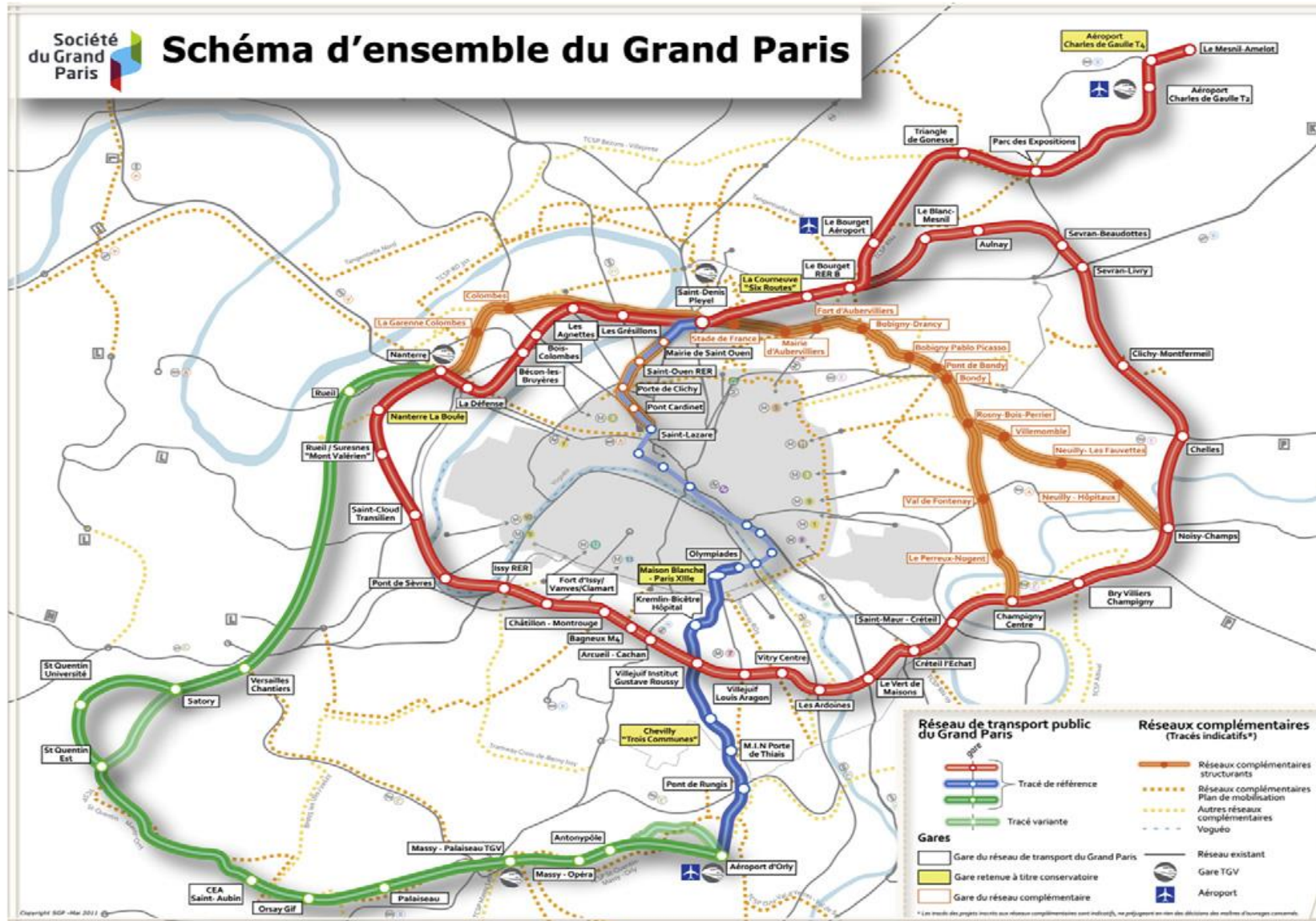
The causal structure of the PGP's effects

The PGP PUBLIC TRANSIT MEGAPROJECT IS BUILT

MEGAPROJECT REDUCES PUBLIC TRANSIT TRAVEL TIMES

TRIPS SWITCH TO PUBLIC TRANSIT

ROAD CONGESTION IMPROVES

CAR TRAVEL TIMES FALL

ACCESSIBILITY IMPROVES
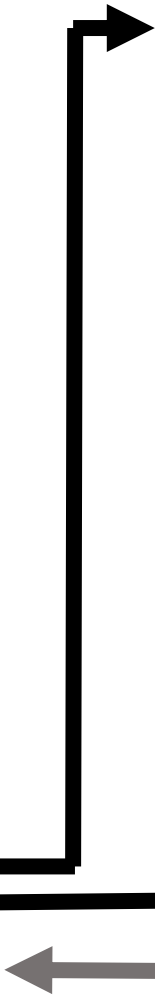
PRODUCTIVITY RISES

Real wages rise
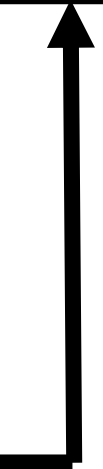
CONSUMER UTILITY RISES

JOBS & POPULATION AGGLOMERATE NEAR THE MEGAPROJECT

Real rents rise

IN-MIGRATION

(negative feedback on utility)

(negative feedback on road congestion and on accessibility)

How the TFP externality is treated in the production function.

Production function $\longrightarrow$ $$X_{rj} = A_{rj} F_{rj}\left(K_{rj}, \mathbf{L}_{rj}, \mathbf{B}_{rj}\right)$$

From Ciccone (2002) for France

TFP (Total Factor Productivity) $\longrightarrow$ $$A_{rj} = C_{rj} \underbrace{\left(\sum_{\forall i} w_i \mathrm{d}_i G_{ij}^{-\beta}\right)^{\alpha}}_{\equiv A_j}, \qquad \alpha = 0.045, \ \beta = 3$$

Gibbons and Graham (2019) provide a survey of estimates for many countries

Jobs density   **Weight of zones**

$$\mathrm{d}_i \equiv \frac{Jobs_i}{Area_i} \qquad w_i \equiv \frac{Jobs_i}{\sum_i Jobs_i} \qquad Jobs_j = N \cdot Pr^e \sum_{ikr} P_{ijkr}^e\left(\mathbf{w}, \mathbf{R}, \mathbf{p}, \mathbf{G}, \mathbf{g}\right),$$

Jobs endogenously determined

Wages, rents, prices, travel costs, travel times

Across modes composite travel times

$$G_{ij} = PROB_{CAR|ij} \times \left(\tau_{ij} + \tau_{ji}\right) + \left(1 - PROB_{CAR|ij}\right) \times \left(TIME_{PT|ij} + TIME_{PT|ji}\right)$$

Car choice probability   **Congested car travel times**   **PGP travel times**

Properties of the TFP equation

- The productivity of jobs in a zone j is influenced more by the jobs in zone i than in zone i':

1) If i and i' are equally accessible to j and equally dense, and i has more jobs than i'

2) If i and i' are equally accessible to j and have equal jobs, and i is denser than i'.

3) If i and i' are equally dense and have equal jobs, and i is more accessible to j than is i'.

The three margins of the TFP externality

1. **Intensive marginal effect:** Higher TFP makes each worker more productive so fewer jobs are needed to produce the same output quantity. (An instance of Schumpetrian job destruction, overlooked by Marshall)

1. **Extensive marginal effect:** Higher TFP lowers cost and price so the quantity demanded increases and more jobs are created.

3. **Super-extensive margin:** As utility improves because of the TFP externality, in-migration increases population. The higher population increases the TFP and there is a positive feedback effect.

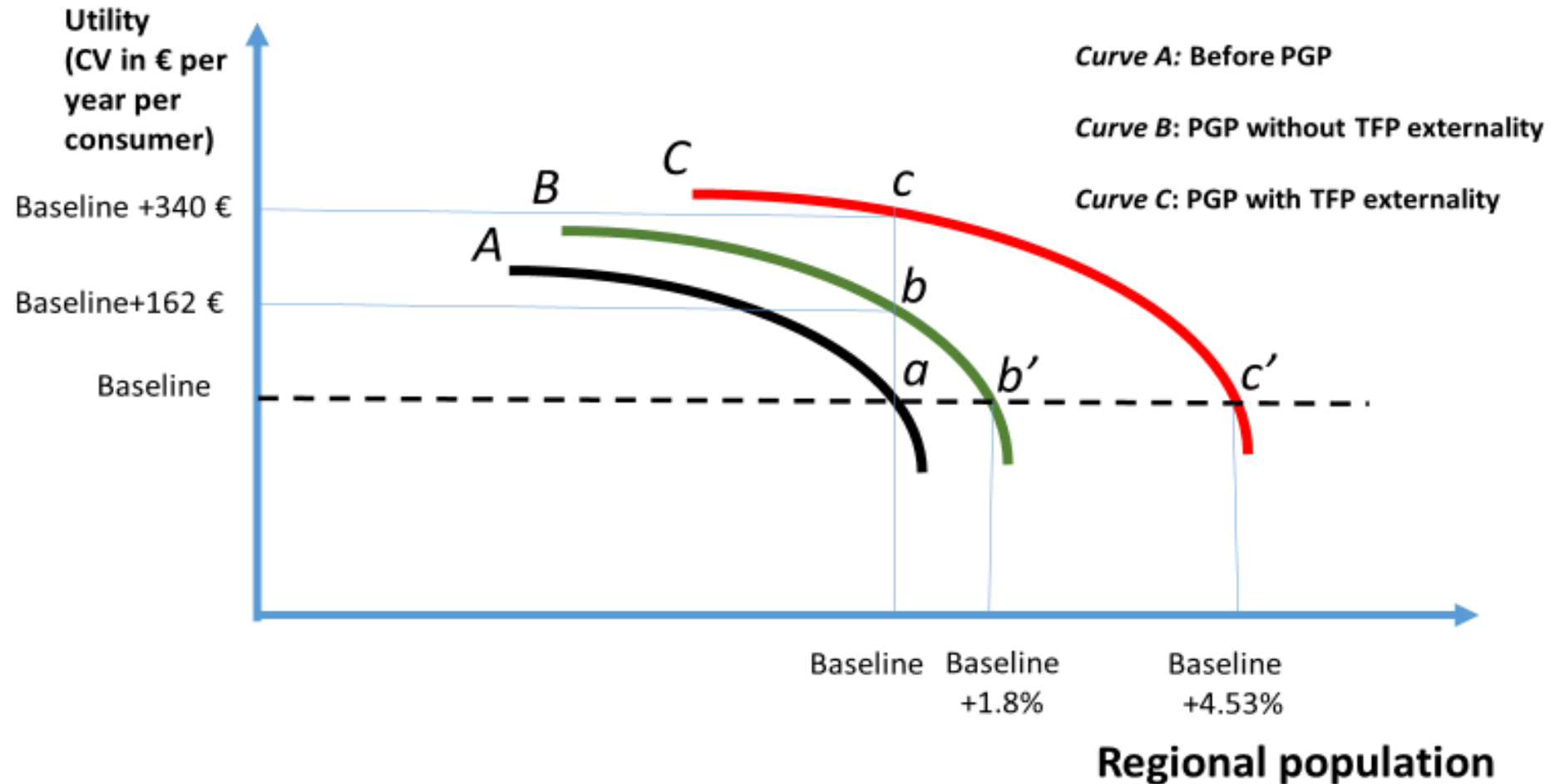# Comparison to literature's simple partial equilibrium models

	Traffic Congestion	TFP externality	Distortionary tax	Mono- or polycentric	Long run or short run	Non-work travel
Parry & Bento 2001	Yes	No	Income	Monocentric	Short run	None
Arnott 2007	Yes	Yes	None	Monocentric	Short run	None
Venables 2007	No	Yes	Income	Monocentric	Long run	None
Anas & Chang 2020	Yes	Yes	Income & sales	Polycentric	Short and long run	Yes

	Wages/ Income	Rents	Product prices	Exports/Imports	Production	Buildings
Parry & Bento 2001	Exogenous/ Endogenous	No	Exogenous (numeraire)	No	No	No
Arnott 2007	Exogenous/ Endogenous	Yes	Exogenous/ Endogenous	No	No	No
Venables 2007	Private average product	Yes	Exogenous/ Endogenous	No	Yes	No
Anas & Chang 2020	Value of private marginal product	Yes	Endogenous	Yes	Yes	Yes

Welfare analysis

$$W \equiv Welfare \ per \ consumer = \underbrace{CV_{consumer} + CV_{importer}}_{Consumer \ benefits} + \frac{\rho}{N} \underbrace{\left[\sum_{i,k=0,\ldots,5} \left(S_{ik}V_{ik} - S_{ik}^{Base}V_{ik}^{Base} \right) \right]}_{Annualized \ real \ estate \ gains}$$

$$+ \underbrace{\frac{1}{N} \left(\Delta Toll \ Rev. + \Delta Tax \ Rev. \right)}_{Fiscal \ surplus}.$$

$$Social \ benefit\text{-}to\text{-}cost\text{-}ratio = \frac{W \times N}{Annualized \ project \ cost}$$

Effects of the PGP in the absence of congestion pricing

Utility
(CV in € per
year per
consumer)

Curve A: Before PGP

Curve B: PGP without TFP externality

Curve C: PGP with TFP externality

Baseline +340 €

Baseline+162 €

Baseline

C

B

A

c

b

a   b'   c'

Baseline   Baseline
+1.8%

Baseline
+4.53%

Regional population

Effects of the PGP in the presence of congestion pricing
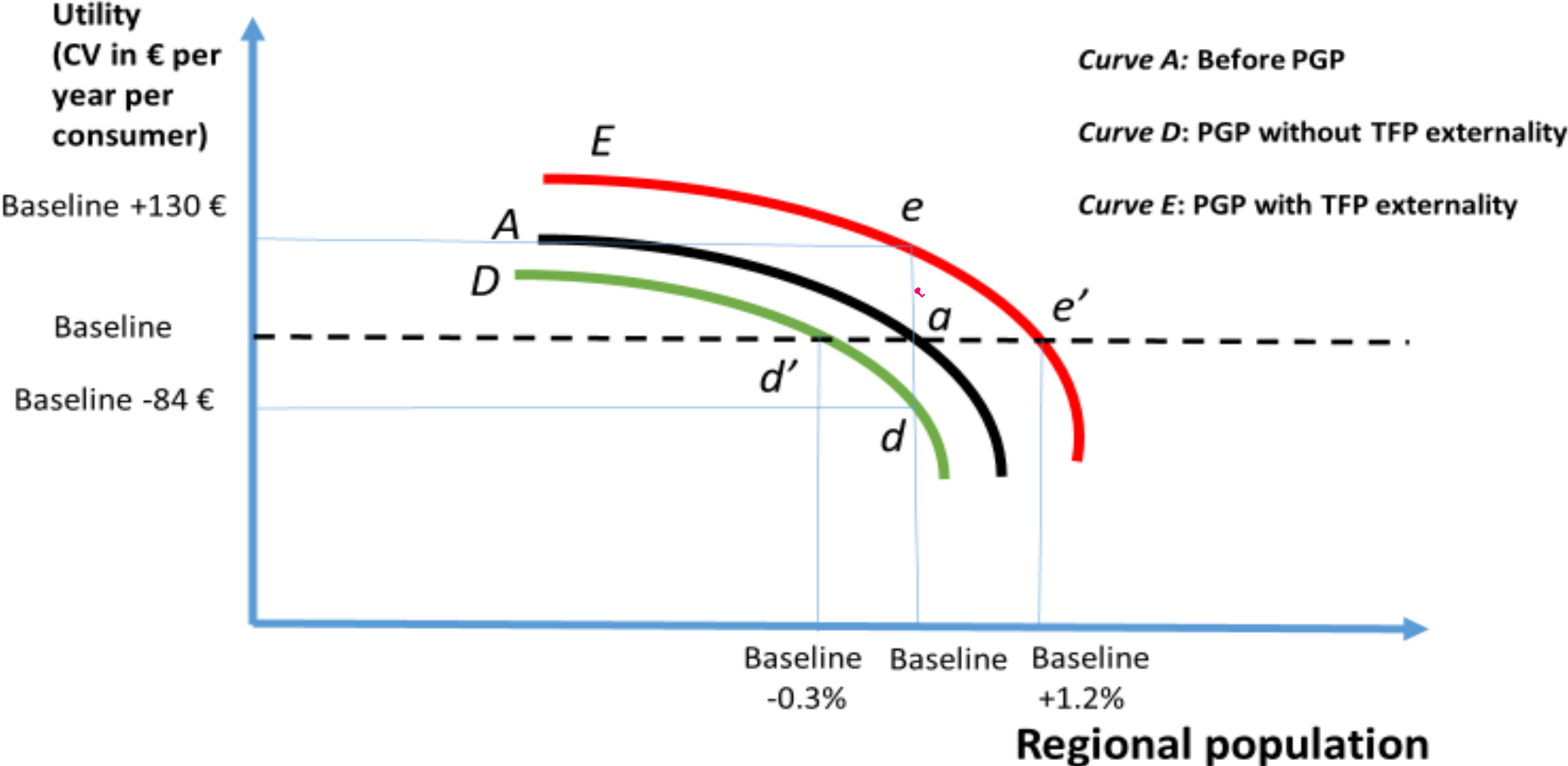
Interactions among the market failures (MF)

- **MF1: Traffic congestion**
- **MF2: TFP externality**
- **MF3: Distortionary taxes (income tax, sales tax)**

1) There is weak interaction between the traffic congestion externality and the TFP externality.

2) There is a strong negative effect of the TFP externality on the income and sales tax revenues.

3) There is a strong negative interaction between congestion pricing and the TFP externality.

The effect of the TFP externality on sales tax revenue
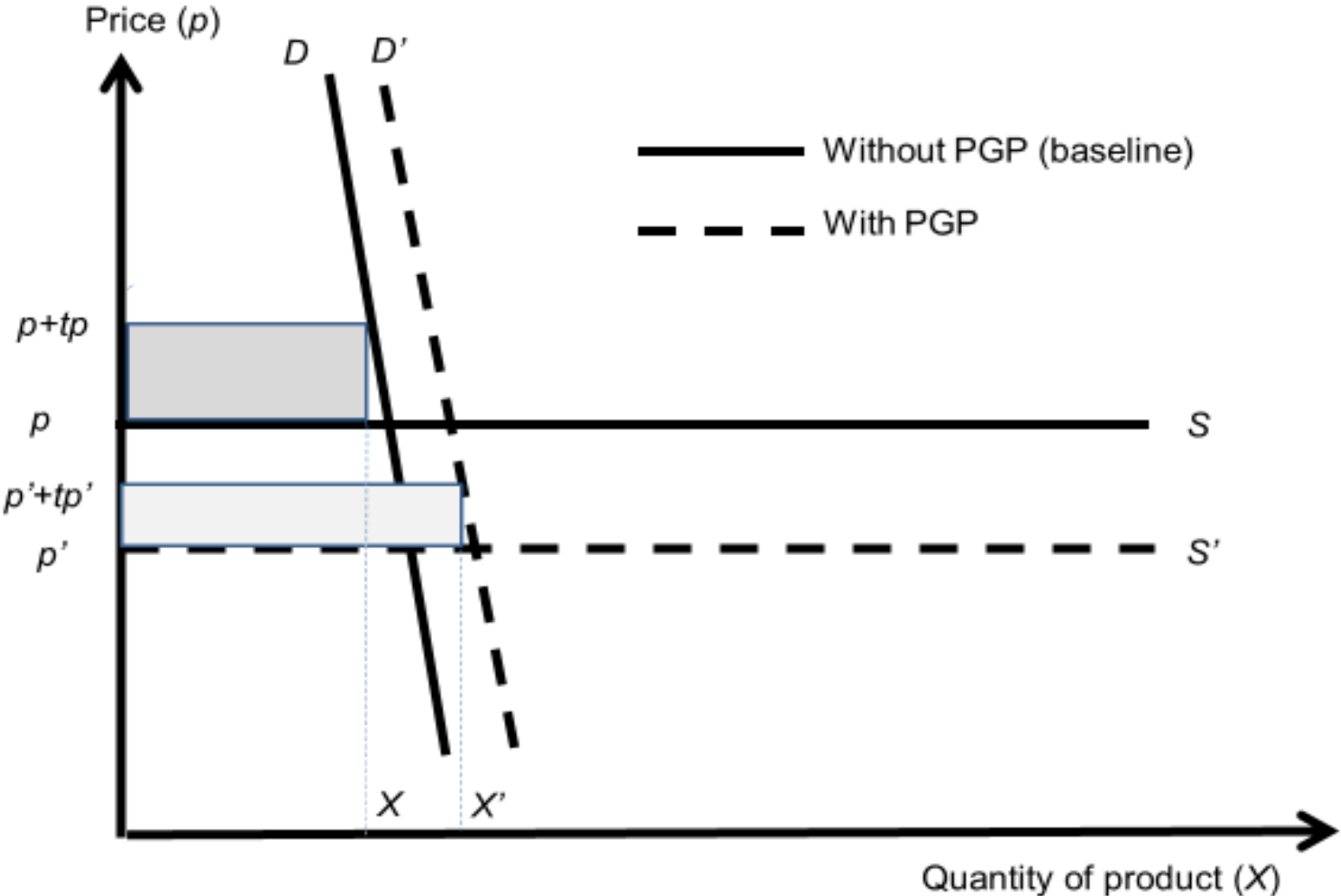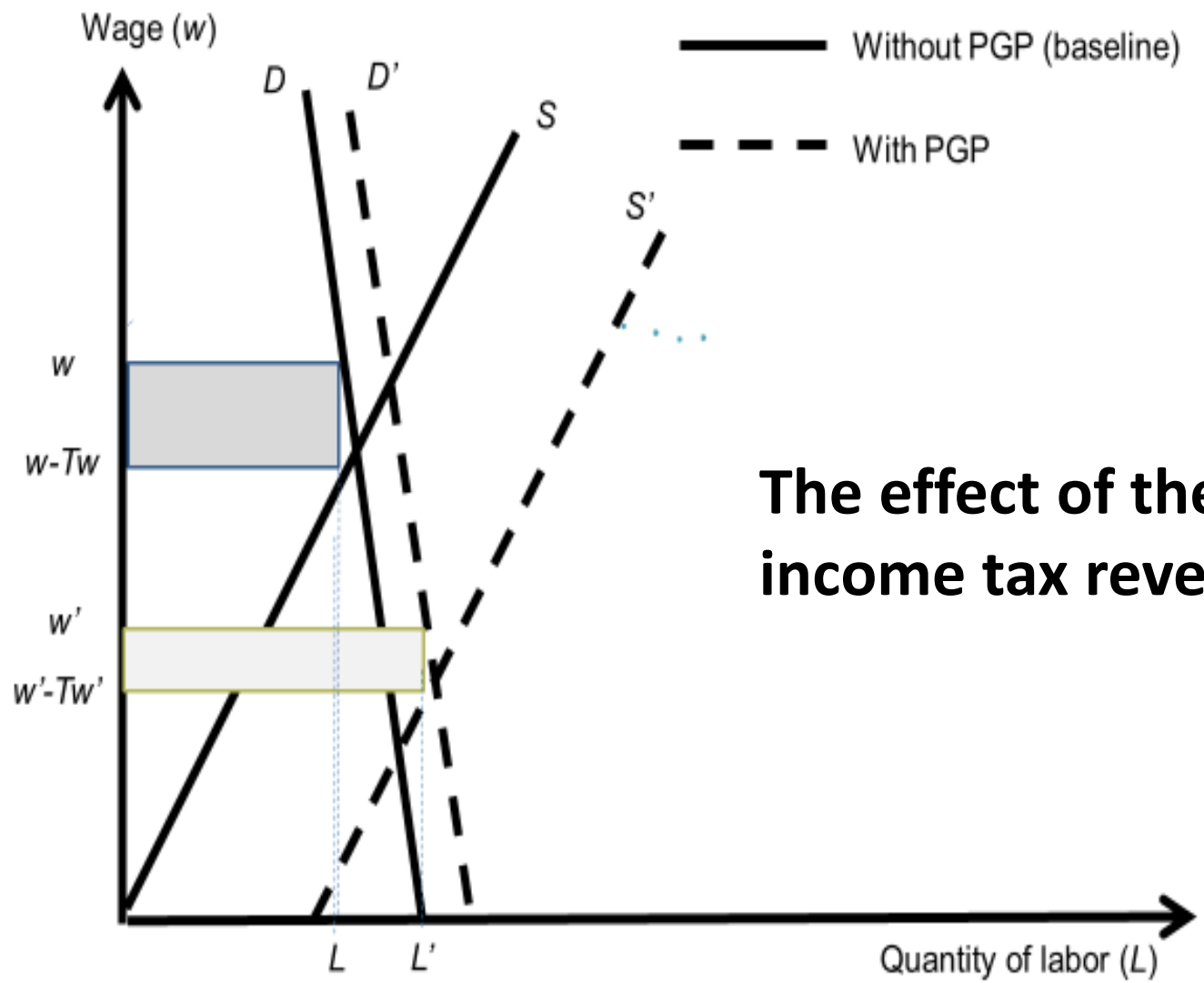
The effect of the TFP externality on income tax revenue

	GPP in 2035 - closed city		GPP in 2035 - open city		GPP in 2035 with congestion pricing - closed city	
	Change due to GPP with constant productivity	Additional change due to GPP with endogenous productivity	Change due to GPP with constant productivity	Additional change due to GPP with endogenous productivity	Change due to GPP with constant productivity	Additional change due to GPP with endogenous productivity
Welfare [= a + b + c + d + e]	**175**	**315**	**-4**	**136**	**243**	**147**
a. **Consumer CV**	162	178	-1	1	-84	214
b. **Real estate values**	1	-15	61	66	-51	-20
c. **Tax revenues**	7	-84	-211	-429	-280	-117
Sales tax	3	-44	-107	-213	-145	-59
Income tax	4	-41	-105	-214	-135	-57
d. **Congestion toll revenue**	0	0	0	0	422	3
e. **Importer CV**	5	236	147	498	236	67
Productivity externality	416	-5	410	-15	412	-7
Road congestion externality	513	3	520	15	422	3
GPP cost	132	0	130	-3	132	0
Benefit-to-cost ratio [= Welfare/GPP cost]	1.32	2.39	-0.031	1.101	1.84	1.11
Public cost recovery ratio [= d/(GPP cost - c)]	0	0	0	0	1.02	0.69
Welfare gain as a percent of average income	0.47	0.84	-0.011	0.37	0.66	1.06

Welfare gains as a percent of average incomes

Constant population (short run)   **With congestion pricing**

- Of PGP without TFP externality = 0.47   0.66
- Of PGP with TFP externality   = 1.31   1.06

- **Endogenous population (long run)**

- Of PGP without TFP externality = - 0.01   0.91
- Of PGP with TFP externality   = 0.36   1.34

Social benefit-to-cost ratios

Constant population (short run)   **With congestion pricing**

- Of PGP without TFP externality = 1.33   1.84
- Of PGP with TFP externality   = 3.71   2.95

- **Endogenous population (long run)**

- Of PGP without TFP externality = -0.03   2.53
- Of PGP with TFP externality   = 1.04   3.78

Public cost recovery ratios
= Tolls/(PGP cost –tax revenue changes)

Constant population (short run)

- PGP without TFP externality = 1.02
- PGP with TFP externality   = 0.81

Endogenous population (long run)

- PGP without TFP externality = 1.18
- PGP with TFP externality   = 0.63

Conclusions

(i) The wider benefits are substantial when the megaprojects confer a TFP externality.

(ii) The super extensive margin of in-migration to the region in the long run is the most important.

(iii) The negative income effect of congestion pricing mitigates the in-migration induced by the project.

(iv) The TFP externality reduces nominal output prices and wages, but increases real wages and rents.

   (iv-a) The lower nominal output prices of traded goods confer benefits on those who import from the region as well as those in the region. BUT…

   (iv-b) A higher TFP causes the revenue from income and sales taxation to decrease.

   (iv-c) Negative income effects of congestion pricing on purchasing power cause lower revenue from the distortionary taxes.

(v) The TFP externality has a minor negative interaction with congestion pricing in the short run and a minor positive interaction in the long run.