How Uncertainty Shapes the Spatial Economy

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Uncertainty... over just half of a working life

Employment projections 1982-1995: "*Employment growth in many occupations will be affected by technological change through the mid-1990's. [...] However, despite widespread technological advances, employment will continue to advance in most traditional fields from 1982 to 1995.*" Source: BLS, Occupational employment projections through 1995, Monthly Labor Review, November 1983.

e.g. demand for **Textile operatives** is expected to **grow by 13K** jobs from the current 352K, thus $\mathbf{+3.7\%}$.

Employment projections 1992-2005: "*Employment in the U.S. economy is projected to increase by 26.4 million over the 1992-2005 period.[...] Projections show services providing more than half of the new job growth, [...] while manufacturing employment declines.*" Source: BLS, Industry output and employment, Monthly Labor Review, November 1993.

e.g. demand for **Textile operatives** is expected to **fall by 73K** jobs from the current 360ths, thus $\mathbf{-20.3\%}$.

Employment projections 2002-2010: "*Employment in most apparel and textile occupations will decline because of increased productivity through automation, increasing imports, and offshore assembly*" Source: BLS, Occupational Outlook Quarterly, Spring 2002.

e.g. demand for **Textile operatives** is expected to **fall by** $\mathbf{-2\%}$ **yearly average.**

Motivation 1/2: Backlash against globalization

Evidence of opposition to globalization, Colantone et al. (2021)

- **Aggregate welfare gains** from globalization in long run
- BUT those hinge on **labor reallocation** across jobs, industries and space

Reallocation is "slow" and "selective"

- A 95% reallocation of workers to approach the st. st. from status quo after trade liberalization takes from 9 years (perfect capital mobility) to **over 30 years** (imperfect capital mobility) and **mobility costs are vastly heterogeneous** across regions and sectors Dix-Carneiro (2014)
- Many remain **trapped in bad locations and low-paid jobs**; far beyond what can be explained by plausible frictions (moving costs or idiosyncratic preferences) in models without forward-looking agents Bilal and Rossi-Hansberg (2021)
- *Brazil 2000s*: Spatial-arbitrage mechanisms are dominated by **slow capital adjustment and agglomeration forces** that in +20-year window amplify disparities across regions Dix-Carneiro and Kovak (2017)
- *US 2000s*: Although average welfare across workers' groups increases, some groups experience **losses as high as four times the average gain** Galle et al. (2023)

Motivation 2/2: Uncertainty leads to inaction

Modeling forward-looking choices under **"uncertainty" = variance of returns to agents' factors of production** helps explaining inertia if agents are risk-averse or expected returns decline with volatility:[1]

- increase in volatility of returns freezes hiring and investment decisions and is a major **obstacle to labor reallocation** Bloom (2009)
- calibrated uncertainty shocks can **explain drops in gross domestic product** of around 2.5% Bloom et al. (2018)
- an exogenous increase in real interest rate volatility triggers a **fall in output and consumption** (also in investment, hours of labor supplied, and debt Fernandez-Villaverde et al., 2011)

[1] This is different from looking at uncertainty of trade policy, as in Pierce and Schott (2016) Handley and Limao (2017).

Research question

Role of uncertainty in explaining why people fail to keep up with opportunities opened up by a more spatially integrated world?

In this paper:

[1] Dynamic spatial general equilibrium model with aggregate uncertainty. In the spirit of Dix-Carneiro (2014) and Artuc and McLaren (2015), risk-averse agents make forward-looking choices under rational expectations; but, here: account for aggregate uncertainty

[2] GE multi-country multi-sector with I/O linkages and labor mobility. In the spirit of Caliendo et al. (2019), but with uncertainty and with insight on inter-generational reallocation (Allen and Donaldson, 2020)
- *parent generations* take into account risk of aging and eventually dying
- *new generations* inherit their parent-generation's location (and nothing else)

Main takeaways

Dynamic spatial quantitative trade model with I/O linkages featuring aggregate uncertainty and idiosyncratic risk calibrated to France, shows that:

[1] The **welfare cost of uncertainty** has a magnitude comparable to the one of large trade liberalization shocks[2]

→ agents loose $\approx 1\%$ of net-present value on average, with a range from -0.7% to -1.5%

[2] Optimal **individual policy responses under uncertainty** are responsible for a spatial distribution of labor that deviates substantially from what a perfect foresight scenario would suggest

→ 3% of the workforce fails to reallocate to better jobs, in "normal times"

→ this *wait and see behavior* can affect up-to 10% of the workforce in "bad times" and up to 30% of the workforce in "good times"

→ job in/out-flows range between -20% and $+20\%$, with non-monotone transitional dynamics

[2] Benchmark: Caliendo et al. (2019) quantify the China shock on US labor market as $+0.2\%$ on real GDP, with dispersion across individual labor markets ranging from -0.8% to $+1\%$

Related literature

Quantitative-GE trade literature

- Static models: Eaton and Kortum, 2002, Dekle et al., 2007, Caliendo and Parro, 2015, Monte et al., 2018, Carrere et al., 2020a, Carrere et al., 2020b, Adao et al., 2020 and many other studies summarized in Redding and Rossi-Hansberg, 2017
- Dynamic models under perfect foresight: Dix-Carneiro, 2014, Desmet et al., 2018, Caliendo et al., 2019, Allen and Donaldson, 2020, Dix-Carneiro et al., 2023 with inter-regional and inter-sectoral frictions to labor mobility Artuc et al., 2007, Artuc and McLaren, 2015, with an insight on trade policy as summarized in Caliendo and Parro, 2022

Macro literature on uncertainty and HANK models

- "Effect of uncertainty" - measured as TFP volatility shock - on production decisions Bloom, 2009, Fernandez-Villaverde et al., 2011, Bloom et al., 2018
- Solution methods Ahn et al., 2018, Achdou et al., 2021, Bilal, 2023

Dynamics: discrete time/state + out of steady state + agg. uncertainty

Pioneer literature on transitional dynamics of spatial GE models:

1. State the problem in continuous time
2. Compute the StSt of the model
3. Linearize around the StSt and compute the finite-diff.-approximation
4. Use projection methods to reduce dimensionality of the problem
5. Solve for impulse responses of the reduced model, making use of

- Eigenvalue decomposition of the linearized model Kleinman et al. (2021)
- Master Equation of the linearized continuous Mean Field Game Bilal (2023)

Our approach preserves discrete nature of the data, non-linearity of the model, out-of-StSt dynamics and tractability of aggregate uncertainty. [EES, 2023]

a. State problem in **discrete** space and time
b. Compute finite-difference approximation of the **non-linear model**
c. Write model as a **coupled Mean Field Game**
d. Solve for **piece-wise linear interpolation of the Master Equation**

Plan of the talk

Time, space and geographically located markets

- Time is discrete $t = 0, 1, ...$ with infinite horizon
- The economy is a set of spatially segmented **regions** $r = 1, ..., R$
- In each region there are $s = 1, ..., S$ **sectors**
- Each region is populated by a large number of households; they supply 1 unit of labor each in a certain **occupation** $k = 1, ..., K$ and consume a local region-specific aggregate good
- Each region-sector pair (rs) is home to a large number of **competitive firms**; they employ labor and intermediate goods to produce varieties of sector-specific goods
- The triplet region & sector & occupation identifies a **job** $j = \{r, s, k\}$, with $j = 1, ..., J$

Primitives of the model

Multi-sector, multi-region, competitive GE open economy with I/O linkages:

- Varieties are traded across regions subject to *iceberg* trade costs. Perfect competition: the price of a variety is the lowest marginal cost at which the good can be delivered in the region Eaton and Kortum (2002)
- Households supply labor in local competitive markets and consume a region-specific CES aggregator of sectoral goods, there are no means of saving Caliendo et al. (2019)
- Production of intermediate varieties requires a **region & sector-specific productivity** A_t^{rs}, which evolves as a stationary Markov stochastic process over space and time, and a variety-specific idiosyncratic efficiency shifter Caliendo et al. (2018)
- **Aggregate uncertainty is about realizations of region-sector TFP**

Households

Households are heterogeneous in two dimensions:

1. **Job**. Each point in time households make a choice about which job to start at in the next period

2. **Age**. Each point in time households find themselves in one age spell $a = \{b, y, o, d\}$

- **b**orn: optimally chooses where to start as a **y**oung household $a = y$ next period, moving from the current location of her "young" parents
- **y**oung: supply labor in a certain job j. Every period a young household becomes old $a = o$ with probability $\lambda^y \in (0, 1)$
- **o**ld: supply labor in a certain job j. Every period old households die $a = d$ with probability $\lambda^o \in (0, 1)$
- **d**ead: drop out of the population

+ A "young" generates a new "born" at a rate $\lambda^b \in (0, 1)$

Benefits and costs of changing job

- At end of period t, household h understands the idiosyncratic tastes $\{\varepsilon^n_{h,t}\}_{n \in J}$ in case she would start at job n
  In the tradition of McFadden (1974), $\boldsymbol{\varepsilon} \sim i.i.d.\ Gumbel$, with variance in taste for jobs governed by $\nu > 0$

- Changing job is costly (moving costs are losses in current utility)
  - born from households in job j pay $\zeta^{bj,n} \geq 0$ to start working in n
  - young households pay $\zeta^{yj,n} \geq \zeta^{bj,n}$ to change job from j to n
  - old households pay $\zeta^{oj,n} \geq \zeta^{yj,n}$ to change job from j to n

Rational households solve a dynamic optimal control problem

- Let $v^{aj}_{h,t}$ be the lifetime value of a household h in job j, age spell a at time t, discounted at rate $\beta \in (0,1)$
- Let c^j_t be the composite consumption good available to *any* household in j at time t (intra-temporal allocation)
- The lifetime value of being in a certain job j at time t

$$v^{bj}_{h,t} = \max_{n \in J} \left\{ \nu \varepsilon^n_{h,t} - \zeta^{bj,n} + \beta \mathbb{E}_t \left[V^{yn}_{t+1} \right] \right\},$$

$$v^{yj}_{h,t} = u(c^j_t) + \max_{n \in J} \left\{ \nu \varepsilon^n_{h,t} - \zeta^{yj,n} + \beta \mathbb{E}_t \left[(1-\lambda^y) V^{yn}_{t+1} + \lambda^y V^{on}_{t+1} \right] \right\},$$

$$v^{oj}_{h,t} = u(c^j_t) + \max_{n \in J} \left\{ \nu \varepsilon^n_{h,t} - \zeta^{oj,n} + \beta \mathbb{E}_t \left[(1-\lambda^o) V^{on}_{t+1} \right] \right\},$$

where $V^{an}_t \equiv \mathbb{E}_h \left[v^{an}_{h,t} \right]$ and $a = \{b, y, o\}$

Solve by age group & job type

- $v_{h,t}^{aj}$ is a random variable, as it depends on the idiosyncratic realization of the events $\{\varepsilon_{h,t}^{n}\}_{n\in J}$
- But uncertainty faced by a single household is the same for everyone in the same age group & job type (aj)
- Thus, taking the expectation $V_t^{aj} \equiv \mathbb{E}_h\left[v_{h,t}^{aj}\right]$ allows us to express the average value of being in a job j at age $a = \{b, y, o\}$
- Bellman equation for the (mean) value of the dynamic optimal control problem of an agent of age a in a job j at time t is:

$$V_t^{aj} = u^a(c_t^j) + \mathbb{E}_h\left[\max_{n\in J}\left\{\nu\varepsilon_{h,t}^{n} - \zeta^{aj,n} + \beta\mathbb{E}_t\left[(1-\lambda^a)V_{t+1}^{an} + \lambda^a V_{t+1}^{(a+1)n}\right]\right\}\right]$$

where $u^b = 0$ and $V_t^{(o+1)n} = 0$ for every time t and job n

Inter-temporal optimality condition: For the marginal mover from a job j to a job n the cost of moving is equal to the discounted expected total gain from moving, considering current value + option value Artuc et al. (2010)

A “closed-form” policy for the inter-temporal problem

- Policy: fraction of households moving from job j to job n at age $a = \{b, y, o\}$ and time t

$$m_t^{aj,n} = \frac{\exp\left(\beta \mathbb{E}_t \left[(1-\lambda^a) V_{t+1}^{an} + \lambda^a V_{t+1}^{(a+1)n}\right] - \zeta^{aj,n}\right)^{1/\nu}}{\sum_{i \in J} \exp\left(\beta \mathbb{E}_t \left[(1-\lambda^a) V_{t+1}^{ai} + \lambda^a V_{t+1}^{(a+1)i}\right] - \zeta^{aj,i}\right)^{1/\nu}}$$

- Aggregate law of motion: aggregating migration flows, new births and deaths yields the distribution of households across jobs in the next period

$$L_{t+1}^{yj} = (1-\lambda^y) \sum_{i=1}^{J} \left(m_t^{yi,j} L_t^{yi}\right) + \lambda^b \sum_{i=1}^{J} \left(m_t^{bi,j} L_t^{yi}\right)$$

$$L_{t+1}^{oj} = (1-\lambda^o) \sum_{i=1}^{J} \left(m_t^{oi,j} L_t^{oi}\right) + \lambda^y \sum_{i=1}^{J} \left(m_t^{yi,j} L_t^{yi}\right)$$

such that total labor force in a job j at time $t+1$ is $L_{t+1}^{yj} + L_{t+1}^{oj}$

Equilibrium

Given

- a predetermined distribution of the labor force $\boldsymbol{L}_t \equiv \{L_t^{rsk}\}_{r=1,s=1,k=1}^{R,S,K}$
- a current realization of region-sector TFP $\{A_t^{rs}\}_{r=1,s=1}^{R,S}$ out of Z-many possible realizations of an exogenous stochastic process

The **within-period equilibrium** consists of wages $\{w_t^{rsk}\}_{r=1,s=1,k=1}^{R,S,K}$, prices $\{x_t^{rs}\}_{r=1,s=1}^{R,S}$ and expenditure shares $\{\pi_t^{rs,ns}\}_{r=1,s=1,n=1}^{R,S,R}$ such that

- $R \cdot S \cdot K = J$ local labor markets clear
- $R \cdot S$ local output markets clear
- $R \cdot R \cdot S$ trade flows balance at the regional level

The **dynamic equilibrium** with $\eta = 2$ age groups, i.e. $\{y, o\}$, consists of an $\eta \cdot J \cdot Z$-dimensional column vector of positive real values $\boldsymbol{V}(\boldsymbol{L}_t)$, and an $[\eta \cdot J \times J]$-dimensional right-stochastic transition matrix $\boldsymbol{M}(\boldsymbol{L}_t)$, such that

- the system of $\eta \cdot J \cdot Z$ Bellman equations is satisfied
- the aggregate law of motion satisfies point-wise (i.e. at each frequency) the $[\eta \cdot J^2]$-many optimal policies

Plan of the talk

1. **Introduction**
2. **Model**
3. **Implications**
4. Simulation

What do we learn from this setup?

Expected lifetime value function at time t for an agent of age $a = \{b, y, o\}$ who is in a job j

$$V_t^{aj} = u^a(c_t^j) + \mathbb{E}_h \left[\max_{n \in J} \left\{ \nu \varepsilon_{h,t}^n - \zeta^{aj,n} + \beta \mathbb{E}_t \left[(1 - \lambda^a) V_{t+1}^{an} + \lambda^a V_{t+1}^{(a+1)n} \right] \right\} \right]$$

$\Longrightarrow$ Shocks that households can insure (arbitrage) against by changing optimally location, sector and occupation

$\Longrightarrow$ Shocks that households cannot insure against, such as aging

$\Longrightarrow$ Moving costs are certain and sorted $\zeta^{oj,n} \geq \zeta^{yj,n} \geq \zeta^{bj,n}$

$\Longrightarrow$ Expected lifetime horizon gets shorter with aging

Risk aversion

1. If agents are risk averse, not accounting for aggregate uncertainty implies a systematic over-estimation of speed of reallocation vs perfect foresight.

- Call $x_{t+1}^{a'n}$ the state at time $t+1$ contingent on the realization of the idiosyncratic shock $a' = \{a, a+1\}$ for a household moving to job n by the beginning of time $t+1$
- If the function V is increasing and concave, then Jensen's inequality implies

$$\mathbb{E}_t\left[(1-\lambda^a)V\left(x_{t+1}^{an}\right) + \lambda^a V\left(x_{t+1}^{(a+1)n}\right)\right] \leq (1-\lambda^a)V(\mathbb{E}_t[x_{t+1}^{an}]) + \lambda^a V(\mathbb{E}_t[x_{t+1}^{(a+1)n}])$$

which holds with equality if and only if there is perfect foresight with respect to aggregate uncertainty shocks, such that both $V(x_{t+1}^{an})$ and $V(x_{t+1}^{(a+1)n})$ are not treated as random variables. ■

Aggregate uncertainty trap

2. Due to aggregate uncertainty, more households make the rational choice to spend a greater portion of their life in relatively bad jobs.

- Consider two jobs $\{n, j\}$ with the same fundamentals and identical realization of aggregate stochastic shock at time t, such that $V\left(x_t^{an}\right) - V\left(x_t^{aj}\right) = 0$ and $\mathbb{E}_t\left[V\left(x_{t+1}^{an}\right) - V\left(x_{t+1}^{aj}\right)\right] \approx 0$
- Assume a positive productivity shock in job n only such that ex-post we have $V\left(x_{t+1}^{an}\right) - V\left(x_{t+1}^{aj}\right) > 0$
- Moving decisions are made at time t by looking at:

$$\begin{array}{ll} V^{an}\left(x_{t+1}\right) - V^{aj}\left(x_{t+1}\right) & \text{Under perfect foresight} \\ \mathbb{E}_t\left[V\left(x_{t+1}^{an}\right) - V\left(x_{t+1}^{aj}\right)\right] & \text{Under rational expectations but uncertainty} \end{array}$$

$\Longrightarrow$ By Jensen's inequality, with risk-averse agents facing uncertainty under rational expectations **a greater fraction of households remains in a region that has become worse** than with rational agents under perfect foresight. ■

Not-insurable heterogeneity

3. Not-insurable risks make the option value of reallocation worse for households who have become less mobile.*

- For every positive function V the sorting in moving cost $\zeta^{oj,n} - \zeta^{yj,n} \geq 0$ implies

$$V\left(x_t^{yj}\right) - V\left(x_t^{oj}\right) =$$
$$\zeta^{oj,n} - \zeta^{yj,n} + \beta\left\{(1-\lambda^y)\mathbb{E}_t\left[V\left(x_{t+1}^{yn}\right)\right] + (1-\lambda^y-\lambda^o)\,\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right]\right\} > 0$$

- Let $(1-\lambda^y)\mathbb{E}_t\left[V\left(x_{t+1}^{yn}\right)\right] + \lambda^o\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right] < (1-\lambda^o)\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right]$ then

if
$$(1-\lambda^y-\lambda^o) < 0 \implies (1-\lambda^y)\mathbb{E}_t\left[V\left(x_{t+1}^{yn}\right)\right] < (1-\lambda^y-\lambda^o)\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right] < 0 \quad \nexists$$

if $(1-\lambda^y-\lambda^o) > 0 \implies V\left(x_t^{yj}\right) + \zeta^{yj,n} - V\left(x_t^{oj}\right) - \zeta^{oj,n} =$
$$\beta\left[(1-\lambda^y)\mathbb{E}_t\left[V\left(x_{t+1}^{yn}\right)\right] + \lambda^o\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right]\right] - \beta(1-\lambda^o)\mathbb{E}_t\left[V\left(x_{t+1}^{on}\right)\right] > 0 \quad \nexists$$

by contradiction, the continuation value - in every job - is higher for households with lower moving costs to begin with. ■

*This is different from saying that the new generation inherits a less favorable location to start with: $\zeta^{bk,n} > \zeta^{bl,n}$ is (bad) luck but has nothing to do with risk of aging.

Plan of the talk

1. **Introduction**
2. **Model**
3. **Implications**
4. **Simulation**

- A toy model
- Simulation based on French data

A toy simulation

Consider a minimal setup with 2 symmetric regions, 1 sector, 1 occupation and solve for the production equilibrium with log-utility, symmetric bilateral trade cost $\tau = 1.5$ and trade elasticity $\eta = 4$. Parameters that discipline inter-temporal reallocation:

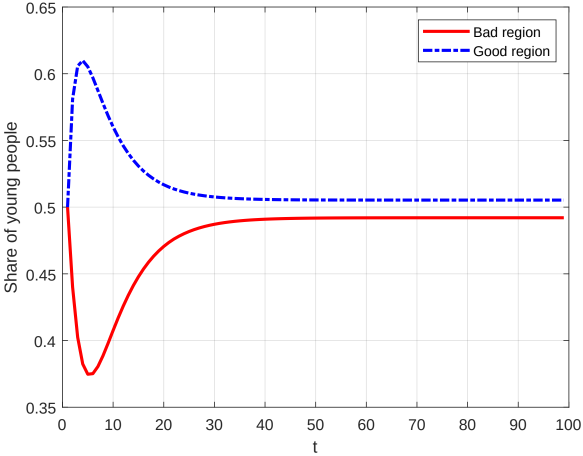
symbol	**description**	**value**	**source**
β	discount factor (yearly)	0.95	C.D.P. 2019
ν	1/migration elasticity	5.34	C.D.P. 2019
$\zeta^o, \zeta^y, \zeta^b$	moving costs (real yearly wage)	$2.7, 1.4, 0.35$	DixC. 2014

- estimates of aggregate TFP volatility by Bloom et al. 2018

	low	**high**
aggregate uncertainty	0.67	1.72

Simulation 1: uncorrelated change in TFP, same uncertainty

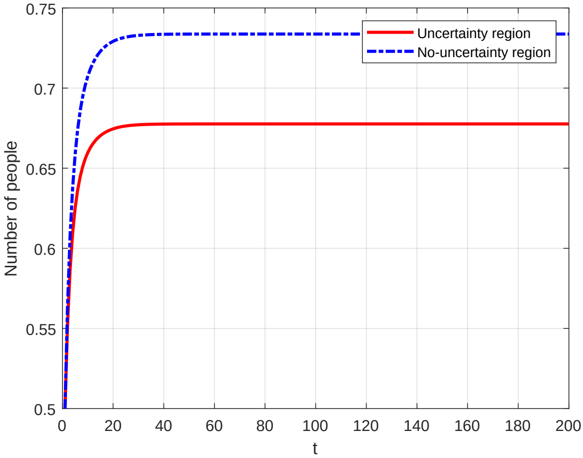
Permanent change in TFP in a region by 38% (C.P.R.S. 2018 "*silicon valley*")



$\Longrightarrow$ Good opportunities are better taken by young people.

Simulation 2: uncorrelated change in uncertainty, TFP constant

One region switches from low uncertainty to high uncertainty, although actual realizations of TFP happen to be the same over time



$\Longrightarrow$ Uncertainty is a penalty even if "fundamentals" do not change.

Simulation based on French data

The state of the dynamic optimal control problem consists of 5 dimensions (region, sector, skill, age, TFP vector) over a grid of 43,120 nodes.

- **individual deterministic state** = 2,156 jobs; i.e. 22 regions, 49 sectors, 2 skill types.
- **individual stochastic state** = 2 age groups; "young" and "old"; the value function and policies for the "born" generation are implied.
- **aggregate stochastic state** = 10 states of nature; i.e. 5 region-sector specific realizations of TFP (1,078 dimensional vector) in 2 volatility regimes.

A solution of the model consists of

- A piece-wise linear function $\boldsymbol{\mathcal{V}}$ defined on a $[4,312 \times 10]$-dimensional grid of positive, bounded real values
- A piece-wise linear function $\boldsymbol{\mathcal{M}}$ defined on a $[2,156 \times 2,156]$-dimensional right-stochastic matrix, for each realization of stochastic states

Taking the model to the data

(a) NUTS2 regions in France and a ROW; WIOD sectors; emp. and wages in France are at region, sector and occupation (2 skill levels)

(b) production and trade elasticities:
- ϵ_{sk} = fraction of labor cost of occupation k on total labor cost
- γ^{rs} = cost of labor over total costs of production, by region and sector
- $\gamma^{rs,rs'}$ = fraction of spending of sector s in goods from sector s' over total spending in intermediates of sector s for France
- trade elasticities θ^s from Caliendo and Parro, 2015

(c) calculate trade costs $\tau_t^{rs,r's}$ by inverting the gravity equation using observed flows and domestic absorption, given trade elasticities, as in Novy, 2013

Challenges that are specific to this project:

#1 TFP in levels

#2 stochastic process of TFP

#3 moving costs

#4 the aggregate deterministic state, i.e. distribution of the population across jobs, evolves endogenously

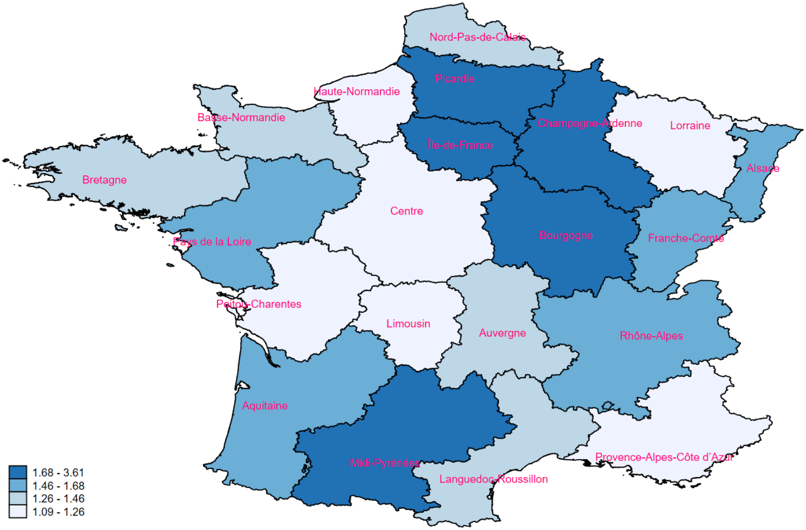
#1 TFP levels

The model implies a region-and-sector specific production function:

$$Y_t^{rs} = \frac{P_t^{rs}}{\Gamma^{rs}} \frac{(A_t^{rs})^{\gamma^{rs}}}{(\pi_t^{rs,rs})^{\frac{1}{\theta^s}}} \left[\left(\prod_{k=1}^{K} L_t^{rsk} \right)^{\epsilon_{sk}\gamma^{rs}} \prod_{s'=1}^{S} \left(M_t^{rs,rs'} \right)^{\gamma^{rs,rs'}} \right]$$

- For each region r sector s we observe value of gross output Y_t^{rs}, employment L_t^{rsk}, material inputs $M_t^{rs,rs'}$, trade shares $\pi_t^{rs,rs}$ and we have production and trade elasticities at hand
- Price index P_t^{rs}/Γ^{rs} for the composite good in region r sector s is obtained (up to a sector-specific constant) by regressing EK-normalized import shares on *region of origin & sector* and *region of destination & sector* fixed effects, given trade costs and trade elasticities
- We use relative output price differences across sectors from the Groningen Growth and Development Centre to scale the price index

Map: TFP levels across French regions in 2012



#2.a TFP stochastic process

1. Assume AR(1) process for region and sector specific TFP

$$\ln A_t^{rs} \quad = \quad \mu^{rs} + \rho \ln A_{t-1}^{rs} + \sigma^{rs} \varepsilon_t^{rs}, \quad \varepsilon_t^{rs} \sim \mathcal{N}(0,1)$$

2. OLS estimation on 2003-2014 yearly data, 22 regions 49 sectors

ρ	μ^{rs}_{5pct}	μ^{rs}_{95pct}	σ^{rs}_{5pct}	σ^{rs}_{95pct}
0.623	-0.267	4.485	0.058	0.403

σ^{rs}_{5pct} corresponds to region *Rhone-Alpes (Lyon)*, sector *Manufacture of computer, electronic and optical products*

σ^{rs}_{95pct} corresponds to region *Nord-Pas-de-Calais (Lille)*, sector *Services to people and business (rental, travel, security, admin. support)*

3. Discretization of region and sector-specific TFP support on 5 nodes over 2 different volatility regimes using Tauchen's method

#2.b Uncertainty shock, neutral for the expected value of TFP

To shed light on the effect of uncertainty in isolation we adjust the 5 nodes describing the support of TFP under the high uncertainty regime such that, given the estimated transition probabilities[3]

- the expected TFP is the same under both regimes
- the central moment is the same under both regimes

Example: job 1697 corresponds to region *Rhone-Alpes (Lyon)*, sector *Manufacture of motor vehicles*, employs 13,310 workers in the year 2012 and the nodes of the TFP support are

regime	very bad	bad	central	good	very good
low uncertainty	0.52	0.76	1.11	1.61	2.34
high uncertainty	0.44	0.64	1.11	1.35	1.96

The probability of **remaining** on the central node is equal to:
98.7% under low uncertainty regime, i.e. $\sigma \equiv 0.058$
22.3% under high uncertainty regime, i.e. $\sigma \equiv 0.403$

[3] Therefore, we are calibrating the low uncertainty scenario.

#3.a Moving costs (scaled by the "moving elasticity" $1/\nu$)

Matched emp.-emp. admin. data, two waves, 2009-10 and 2012-13, by gender, age, origin, destination, sector and occupation. We follow Artuc and McLaren, 2015, and estimate gross migration flows with PPML

$$\ln(m_t^{a,ij} L_t^{a,i}) = \exp\left(\psi_t^{a,i} + \phi_t^{a,j} - \frac{\zeta^{a,ij}}{\nu}\right) + \varepsilon_t^{a,ij} \ , \quad j = \{r, s, k\},\ a = \{o, y\}$$

where $\psi_t^{a,i}$ is a *origin & year* fixed effect and $\phi_t^{a,j}$ is a *destination & year* fixed effect, with modeling moving costs as

$$-\frac{\zeta^{a,ij}}{\nu} \equiv \beta_1 \ln(\mathit{Distance}^{rr'}) \times \mathbf{I}_{t(r \neq r')} + \beta_2 \mathit{Switch\ region}_t^{r'} + \beta_3 \mathit{Switch\ sector}_t^{s'} + \beta_4 \mathit{Switch\ occupation}_t^{k'} + \beta_5 \mathit{Switch\ region\ and\ sector}_t^{r's'}$$

Estimated moving costs, origin and destination fixed effects explain $> 97\%$ of the variation in gross migration flows.

#3.b Moving elasticity that matches stayers

We calibrate the inverse of the migration elasticity $\nu = 0.5215$ to match the overall fraction of stayers in the same job, in the French labor market on average in the two waves 2009-2010 and 2012-2013.

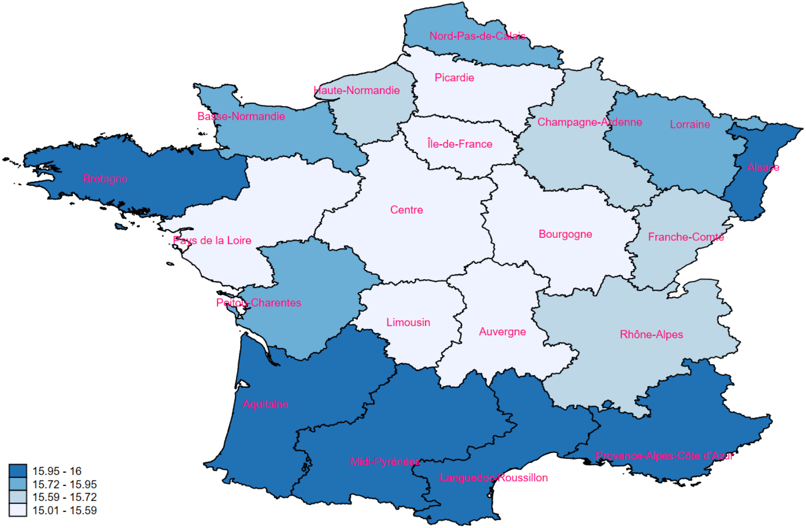
moment	Data	Model
Overall fraction of stayers in the same job	98.1%	96.9%
Fraction of stayers in the same job, among OLD	98.8%	97.4%
Fraction of stayers in the same job, among YOUNG	96.2%	96.4%

On average, moving costs are 7.8% of the lifetime value, i.e. ≈ 4 times the annuity income, for OLD households.

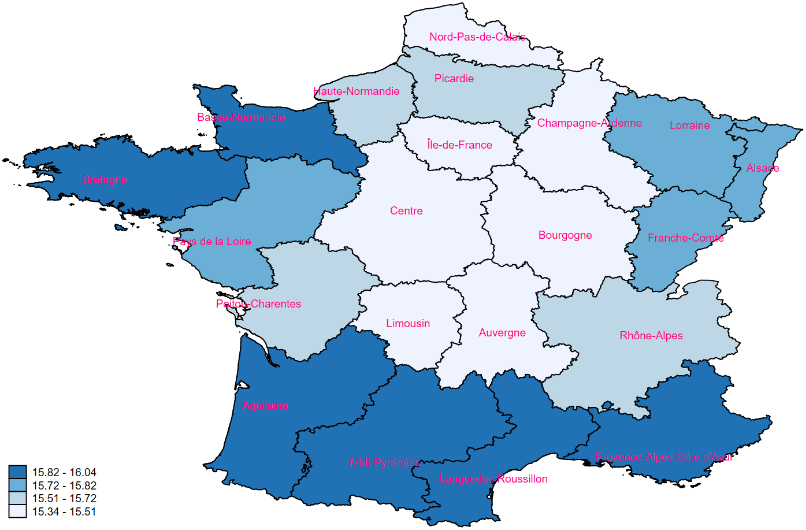
On average, moving costs are 3.6% of the lifetime value, i.e. ≈ 2 times the annuity income, for YOUNG households.

To compare, Artuc and McLaren (2015) on US labor market find: *"given our estimate of $1/\nu = 1.62$ and hence $\nu = 0.62$ that implies a moving cost something more than three times an average worker's annual income"*.

Map: moving costs by region, inward



Map: moving costs by region, outward



#4 Control the evolution of the population

1. Poisson rates for idiosyncratic aging shocks
   - $\lambda^o = 3.45\%$ such that avg. length of old age spell is 30 years
   - $\lambda^y = 5\%$ such that avg. length of young age spell is 20 years

2. Birth rate at which the model predicts no change in total population

$$\lambda^b = \frac{\text{Share of old population}_{t_0}}{\text{Share of young population}_{t_0}} \lambda^o \approx 5\%$$

   starting from a given year $t_0 = 2012$ and with the threshold between young and old age being ≈ 40, based on the median age of the French workforce.

3. Time discount factor $\beta = 98.12\%$, that corresponds to the (macro) discount factor based on the average real interest rate in France between 2009 and 2012, circa $3.42\% - 1.5\%$.

Simulation of uncertainty shock

The goal is to quantify a lower bound for the effect of a shock in aggregate uncertainty, net of the role played by risk-aversion.

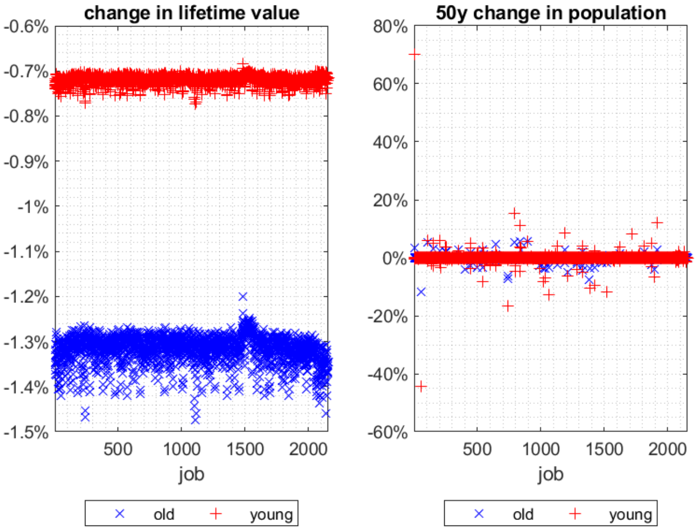
- **No change in observed fundamentals**: for all jobs, we keep the realization of TFP constant over time, and equal to the respective central node
- **Log-utility**: agents are risk averse, but income effect and intertemporal substitution effect cancel out

Compare the solution given the same initial condition and TFP realizations

- under low uncertainty regime
- under high uncertainty regime

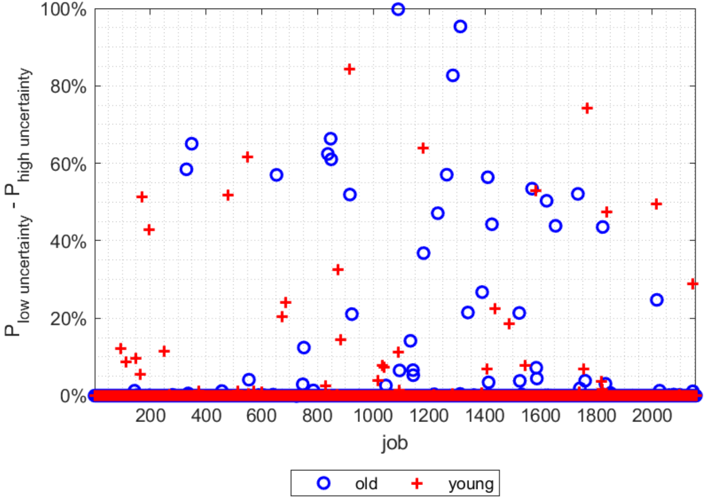
1: Uncertainty induces substantial welfare losses and labor reallocation

Figure 1 Percentage change of lifetime value (left panel) and percentage change of population over 50 years (right panel); across 2156 jobs, by age group.



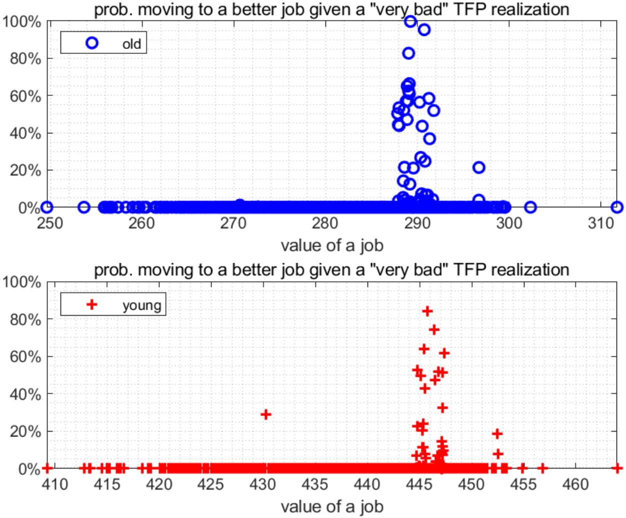
2: Uncertainty "forces" some households to stay in bad jobs

Figure 2 Optimal policy in response to a "Very bad" realization of TFP: difference in the probability of moving to a job with higher lifetime value; across 2156 jobs, by age group.



3: Uncertainty affects the optimal behavior of middle-value jobs

Figure 3 Optimal policy in response to a "Very bad" realization of TFP: difference in the probability of moving to a job with higher lifetime value; across 2156 jobs, by age group.



4: Uncertainty substantially dampens reallocation

Assume that all jobs in France are at their "very bad" TFP realization, then differences in **1-year optimal policy** between low and high uncertainty imply:

Number of OLD household who do not move to better jobs	$830K$
Number of YOUNG households who do not move to better jobs	$2,086K$
Percentage of the total workforce population	10.80%

Assume that all jobs in France are at their "central" TFP realization, then differences in **1-year optimal policy** between low and high uncertainty imply:

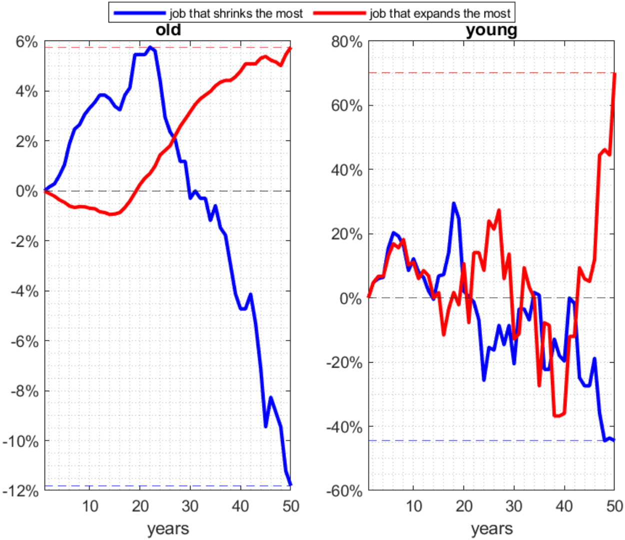
Number of OLD household who do not move to better jobs	$219K$
Number of YOUNG households who do not move to better jobs	$589K$
Percentage of the total workforce population	2.99%

Assume that all jobs in France are at their "very good" TFP realization, then differences in **1-year optimal policy** between low and high uncertainty imply:

Number of OLD household who do not move to better jobs	$6,802K$
Number of YOUNG households who do not move to better jobs	$1,338K$
Percentage of the total workforce population	30.14%

5: Transitional dynamics are non monotone

Figure 4 Evolution of the population in selected jobs over time



Conclusion

We develop a dynamic spatial quantitative model with labor mobility and rational agents making **forward looking decisions under aggregate uncertainty** and facing **non-insurable risk**

- rational households behave differently in a setting with aggregate uncertainty compared to a setting close to perfect foresight, with non-monotone and fairly rich transitional dynamics out-of-steady state
- optimal policy responses under uncertainty explain why a substantial fraction of the population can be stuck in bad jobs

Quantification using French data shows that, given the same fundamentals, greater uncertainty is responsible for

- **large and heterogeneous welfare costs**, ranging between -0.7% and -1.5% of the lifetime value
- optimal policies responses **prevent up to 3% of households from reallocating to better jobs, in "normal times"**
- a *wait and see behavior* that can affect up to 11% **of households in "bad times"** and up to 30% **of households in "good times"**

Appendix

A toy simulation

Consider a minimal setup with 2 symmetric regions, 1 sector, 1 occupation and solve for the production equilibrium with log-utility, symmetric bilateral trade cost $\tau = 1.5$ and trade elasticity $\eta = 4$. Parameters that discipline inter-temporal reallocation:

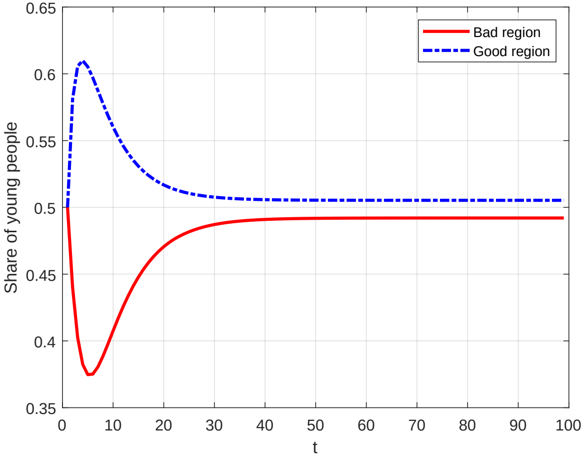
symbol	**description**	**value**	**source**
β	discount factor (yearly)	0.95	C.D.P. 2019
ν	1/migration elasticity	5.34	C.D.P. 2019
$\zeta^o, \zeta^y, \zeta^b$	moving costs (real yearly wage)	$2.7, 1.4, 0.35$	DixC. 2014

- estimates of aggregate TFP volatility by Bloom et al. 2018

	low	**high**
aggregate uncertainty	0.67	1.72

Simulation 1: uncorrelated change in TFP, same uncertainty

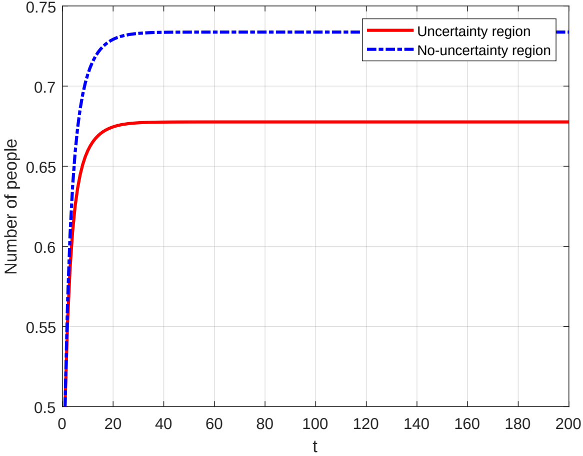
Permanent change in TFP in a region by 38% (C.P.R.S. 2018 "*silicon valley*")



$\Longrightarrow$ Good opportunities are better taken by young people.

Simulation 2: uncorrelated change in uncertainty, TFP constant

One region switches from low uncertainty to high uncertainty, although actual realizations of TFP happen to be the same over time



$\Longrightarrow$ Uncertainty is a penalty even if "fundamentals" do not change.

Related literature looking at capital accumulation

There is a recent literature on spatial capital accumulation, international trade (+ migration) and labor market outcomes; see Kleinman et al. (2021)

- immobile capital owners and mobile *hand to mouth* workers; little help in explaining the effect of uncertainty on location choices
- numerical solutions are based on linearization around a steady state; convenient for approximating the transition paths, but at the expenses of loosing explanatory power on the role of uncertainty

In our model there is no formal capital accumulation, still

[a] the continuation value of a location is the expected value of reaching better locations in the future; "*location-as-asset*" Bilal and Rossi-Hansberg (2021)

[b] optimal forward-looking choices under the risk of aging lead to analogous behavior of young versus old agents as saving and capital accumulation Gourinchas and Parker (2002)

[c] tractability of the numerical solution is preserved without approximation around a steady state [companion paper EES, wp]

Factor accumulation

The model is suited for an analogy with spatial accumulation of capital.

- The distribution of population across locations plays the role of the aggregate deterministic state of the model
- Outflows due to death correspond to exogenous depreciation of the stock of labor in a location
- Inflows and outflows of young and old generation correspond to assets traded in imperfect capital markets, with different degrees of mobility: the young are more mobile than the old; thus, the marginal mover among the young asks for a "lower premium"
- The new-born choose optimally where to locate without a trade-off with consumption in the first period; arbitrage channel (like a mobile asset traded at a risk free rate)

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