The contribution of robots to productivity and GDP growth in advanced economies over 1960-2022

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Content

1. Introduction: motivation and context

- **Abundant literature concerning robot impact on…**
  - **Employment**
    - Among others: Brynjolfsson & McAfee (2014); Autor (2015); Acemoglu & Restrepo (2020); Acemoglu *et al*. (2020); Aghion *et al.* (2020); Aghion *et al.* (2022); Acemoglu *et al.* (2023), …
    - For Kapetaniou & Pissarides (2024) or Shahin *et al.* (2024), the substitution between robots and jobs depends on the country's innovation capabilities, and on openness
    - No consensual results…
  - **Labor share**
    - Among others: Koch & Manuylov (2023) or Shahin *et al.* (2024), both based on analyses on Spanish data, and Shimizu & Momoda (2023), through a theoretical approach, …
    - Consensual results: robot diffusion => labor share decline

1. Introduction: motivation and context

- **Few papers concerning robot impact on productivity**
  - **Graetz & Mitchels (2015, 2018)**
    - Industry level database of 17 countries from 1993 to 2007
    - Increased robots per worker => +0.36pp to annual productivity growth
  - **Acemoglu *et al.* (2020)**
    - French firm level database, manufacturing sector, 2010, 2015
    - Positive impact on productivity
  - **Cette, Devillard & Spiezia (2021, 2022)**
    - Country level analysis
    - 30 advanced countries from 1960 to 2019
    - Use elasticities from G&M (2015, 2018)
  - **Bekhtiar *et al.* (2024)**
    - Same type of data as G&M
    - G&M suffer from a positive because of industry-level heterogeneity
    - They halve the impact
  - **Almeida and Sequeira (2024)**
    - Same type of data as G&M
    - Elasticity of productivity to robotization has at least halved from 2008

1. Introduction: motivation and context

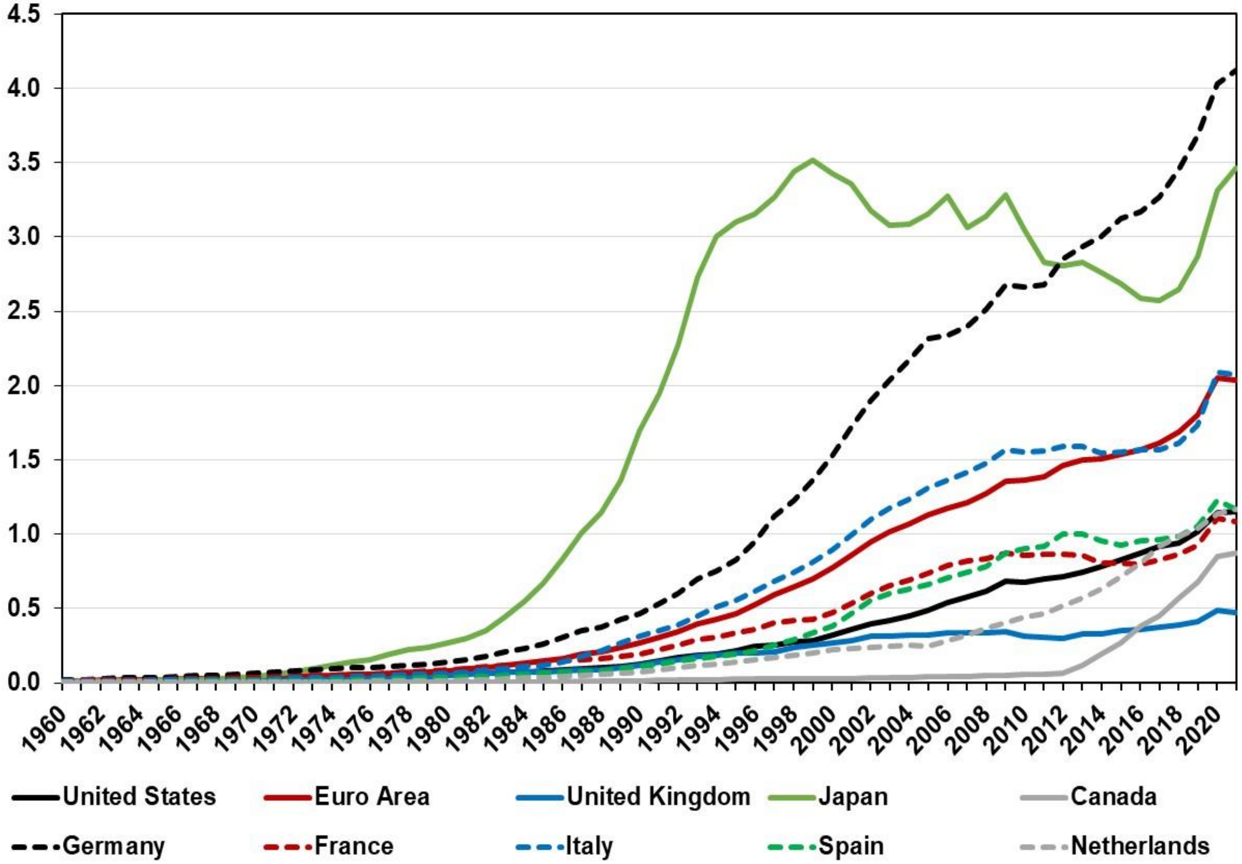
- **Our paper…**
  - Proposes **new evaluation** of robot impact on productivity growth
  - **Country level analysis, 29 countries, 1960 to 2022**
  - Standard **growth accounting approach**
    - Value added elasticity to robots: share of robots in total input remuneration
    - For this, need to estimate robot user cost
  - **Two methodologies** to estimate robot user cost
    - **Methodology 1**: Use the Jorgenson (1963) relation
      Price of robots proxied by the US price index of "*information processing equipment*" from the BEA
    - **Methodology 2**: derived from elasticity of labor productivity to robots estimated by G&M (2015)

2. Data

- **An update of the database built by Cette, Devillard & Spiezia (2021 & 2022)**
  - **Country level, from 1950 to 2022, 29 advanced countries,** Euro Area reconstituted
  - **GDP, employment, hours:** Bergeaud *et al.* (2016), OECD databases, Conference Board TED, & several other databases
  - **Interest rates:** Jordà *et al.* (2019), OECD databases
  - **Robots**:
    - **Industrial robots only**
      ISO definition (ISO 8373:2012): an ‘‘*automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes*’’
    - **Number of robots:** IFR completed by us through estimates on ICTs

3. Robot diffusion

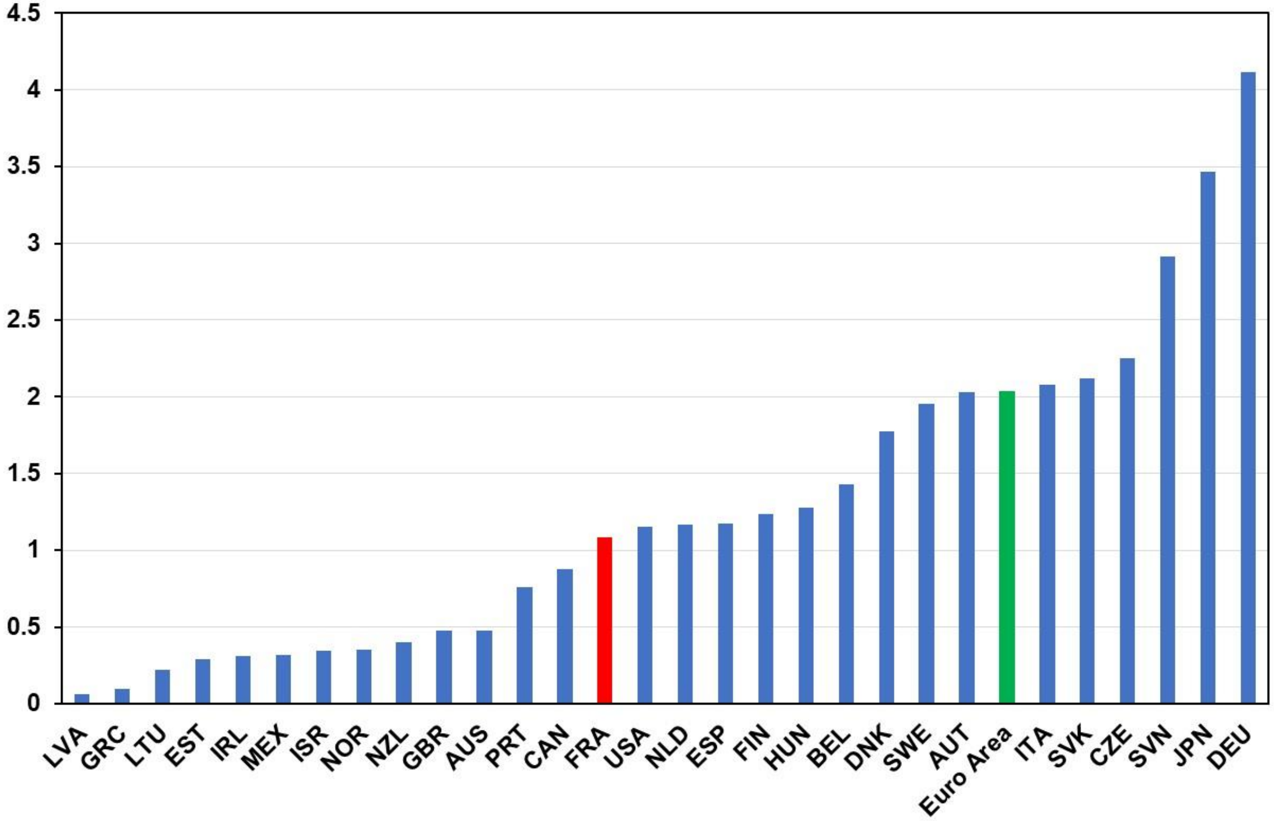
- **Chart 1. Robot diffusion, 1960-2021**
  Number of robots per million hours worked in selected countries



- Continuously increasing diffusion in all countries, except Japan from the early 2000s to the mid 2010s
- Explained by the robot price decrease: G&M (2018) estimate that the price of robots in six major developed economies (France, Germany, Italy, Sweden, the United Kingdom and the United States) in 1990-2005 fell by about 50% in nominal terms and 80% when adjusted for quality

3. Robot diffusion

- **Chart 2. Robot diffusion, 2021**
  Number of robots per million hours worked



- Contrasted level of robot diffusion
- In 2021, highest diffusion: Germany, Japan
- The observed patterns of diffusion also reflect country-specific specializations: robots tend to be concentrated in few manufacturing sectors

4. The two methodologies

- **Growth accounting approach (Solow approach)**
- **Capital deepening contribution channel**
  - $RCG_t = \alpha r_t \,.(\Delta kr_{t-1} - \Delta n_t - \Delta h_t)$
    kr: log of robot capital, *n*: log of employment; *h*: log of hours per worker
  - Törnquist index on $\alpha r_t = (CR_t \,. KR_{t-1})/(PQ_t \,. Q_t)$
    CR: user cost of robot capital, *KR* robot capital, constant price quality adjusted; *PQ*: *GDP* price; *Q*: *GDP* in constant price

4. The two methodologies

- **Methodology 1**
  - $CR_t = PR_t.(i_t - \Delta pr_t + \delta R)$ following Jorgenson (1963)
    PR: price of the robots, quality adjusted; *pr*: in log; *i*: interest rate;
    δR: depreciation rate of robots
  - δR = 10% per year, corresponds to IFR hypothesis
    This rate is higher than 4% to 7% proposed by Klump *et al.* (2021)
    Evaluations robust to other values (δR = 5% or δR = 15% or 20%)
  - Calculation of *KR* is made in two steps
    - We calculate the stock of robots in current value: *KRCV =NR*UVR*
      NR: number of robots, *UVR:* unitary value of robots, from IFR completed by us
    - We divide *KRCV* by a quality-adjusted robot price index (*QARP*)
      QARP: US '*information processing equipment*' price index computed by BEA
      From 1990 to 2005, the annual decrease of this index is 8%, almost the same as G&M (2015)

4. The two methodologies

- **Methodology 2**
  - Same approach as Cette, Devillard & Spiezia (2021, 2022)
  - CR_t is derived from cost-minimisation based on G&M (2015, 2018) elasticities of labor productivity to the number of robots
  - From this methodology, the elasticity of labor productivity to the number of robots per hour worked comes
    - For ¾ via the TFP channel
    - For ¼ via the capital deepening channel

5. Results

- **Results with methodology 1**
  - **Annual robots’ contribution to growth via capital deepening (in pp)**

	1960-1975	1975-1995	1995-2005	2005-2022	1960-2022
United States	0.0010	0.0010	0.0020	0.0011	0.0011
Euro Area	0.0001	0.0012	0.0046	0.0021	0.0020
United Kingdom	-0.0001	0.0008	0.0015	0.0004	0.0008
Japan	0.0000	0.0001	0.0001	0.0000	0.0000
Canada	0.0000	0.0002	0.0002	0.0010	0.0004
Germany	0.0003	0.0020	0.0088	0.0036	0.0033
France	0.0001	0.0008	0.0025	0.0009	0.0011
Italy	-0.0003	0.0015	0.0052	0.0024	0.0025
Spain	0.0003	0.0006	0.0034	0.0019	0.0017
The Netherlands	0.0001	0.0004	0.0008	0.0011	0.0006

- Robots’ contribution to growth is very small according to methodology 1

5. Results

➢ **Results with methodology 2**

- **Annual robots' contribution to growth via capital deepening and TFP (pp)**

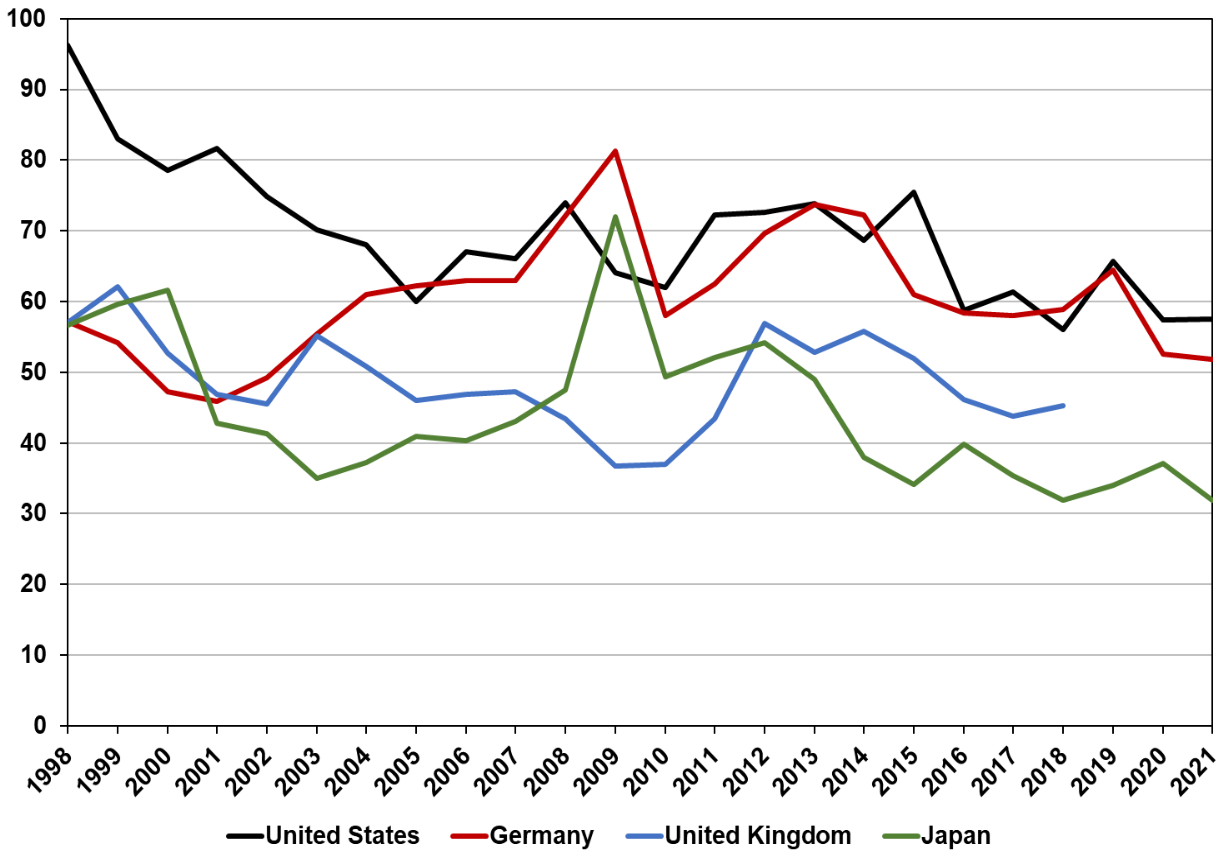
		1960-1975	1975-1995	1995-2005	2005-2022	1960-2022
United States	*Cap. Deep.*	0.00	0.01	0.03	0.04	0.02
	TFP	0.01	0.03	0.08	0.12	0.06
Euro Area	*Cap. Deep.*	0.00	0.02	0.07	0.06	0.04
	TFP	0.01	0.07	0.25	0.19	0.12
United Kingdom	*Cap. Deep.*	0.00	0.01	0.02	0.01	0.01
	TFP	0.01	0.03	0.05	0.03	0.03
Japan	*Cap. Deep.*	0.01	0.19	-0.03	0.00	0.07
	TFP	0.03	0.59	-0.09	0.00	0.19
Canada	*Cap. Deep.*	0.00	0.00	0.00	0.05	0.00
	TFP	0.00	0.00	0.01	0.17	0.06
Germany	*Cap. Deep.*	0.01	0.04	0.15	0.14	0.08
	TFP	0.02	0.13	0.48	0.43	0.25
France	*Cap. Deep.*	0.00	0.02	0.04	0.02	0.02
	TFP	0.01	0.05	0.13	0.07	0.06
Italy	*Cap. Deep.*	0.00	0.03	0.09	0.04	0.05
	TFP	0.01	0.09	0.29	0.13	0.13
Spain	*Cap. Deep.*	0.00	0.01	0.07	0.03	0.03
	TFP	0.01	0.03	0.23	0.11	0.08
Netherlands	*Cap. Deep.*	0.00	0.01	0.01	0.06	0.02
	TFP	0.00	0.02	0.04	0.18	0.07

- Higher contribution than with methodology 1, consistent with other evaluations (G&M, 2015 & 2018, and Cette, Devillard & Spiezia, 2021 & 2022 …)
- Average yearly robots' contribution to productivity growth appears the largest in Germany and Japan

6. Why so low evaluation with methodology 1?

- **More likely explanation:**
  IFR data may underestimate the value of the stock of robots because of an undervaluation of the unitary value of robots (*UVR*)

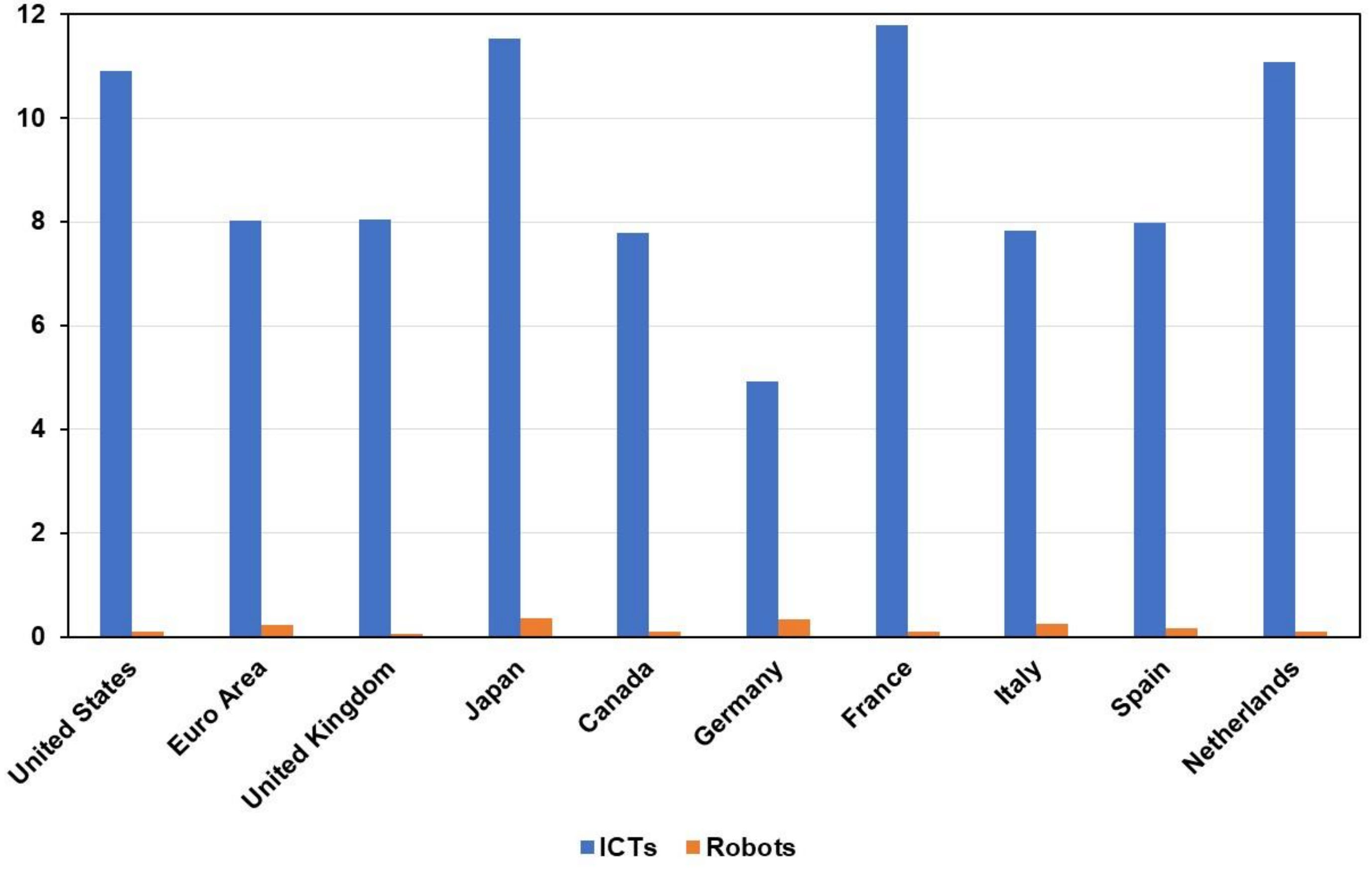
  ○ **Unitary value of robots (UVR) (USD thousand)**



  ○ Low *UVR* from IFR data

6. Why so low evaluation with methodology 1?

- **Low value of robot stock**
- **Ratios of the ICT capital stock and the robot capital stock to GDP, current value, in %, 2021**



- And consequently, low value of the robot capita stock compared to ICTs for instance

7. To conclude

- **Few evaluations** of robot contribution to growth at the country level
- We have proposed **two evaluations**, giving contrasted results
  - **Methodology 1 must underestimate** robot contribution, due to a low evaluation of the Unitary Value of Robots (*UVR*) by IFR
  - **Methodology 2: higher impact**, but still based on G&M (2015, 2018) estimates
    - But G&M (2015, 2018) may overestimate robot contribution, see for instance Bekhtiar *et al.* (2024) or Almeida and Sequeira (2024)
    - => Robot contribution to productivity growth would be large only in some manufacturing industries where the use of robots is itself large
- **Need for further research** on the robots' contribution to growth at the country level