Case Study: Robots, tools, and jobs

Task assignment and the effects of machinery in Brazil

1 Two ways machines change work

Consider the production of a metal component of a larger machine. The production of such machine parts is a big part of what manufacturing output is about and has traditionally employed skilled manual workers that know how to operate the specialized machinery needed for this type of precision work. For example, a numerically controlled lathe (the specialized machine that shapes metal parts) can follow programmed instructions to remove metal and shape the part. Some movements that a machinist previously controlled are now performed by the machine on its own. Still, workers have to set up the equipment, inspect the component, and deal with faults.

A worker using a portable drill or grinder also produces with a machine. The tool supplies power, but the worker positions it, guides it, and judges the result. Better equipment can make the worker faster at an activity that still requires their participation. Both types of machinery (the automatic lathe and the drill) can reduce the time needed to make a component. Do they necessarily have the same effect on employment?

The key distinction is whether a machine takes over an activity or helps a worker perform it. A firm may adopt both kinds at once: after installing an automated cutting machine, it may expand production and equip more workers to finish and assemble its products.

Measuring robots and tools. Brazil's experience between 1997 and 2014 provides evidence on these two types of machinery. A study of machinery imports distinguishes machines that perform workers' tasks, we will call these *robots*, from equipment used by workers, we will call these *tools*. The robot category includes things like programmable machinery as well as industrial robot arms. Tools include things like hand-operated drills, spanners, and wrenches.

The researchers classify 535 machinery products by comparing their customs descriptions with texts about industrial robots, numerical control, and hand and power tools. This uses information about the equipment to distinguish the two groups before estimating their effects on employment.

Customs records identify the value of imports, the importing establishment's industry, and its location. These records are combined with RAIS, Brazil's administrative records of formal employment, to measure employment and average monthly earnings in each industry and local labour market. A local market is a *microregion*, a group of economically connected municipalities. The analysis covers agriculture, mining, and manufacturing, including workers at both importing and non-importing firms.

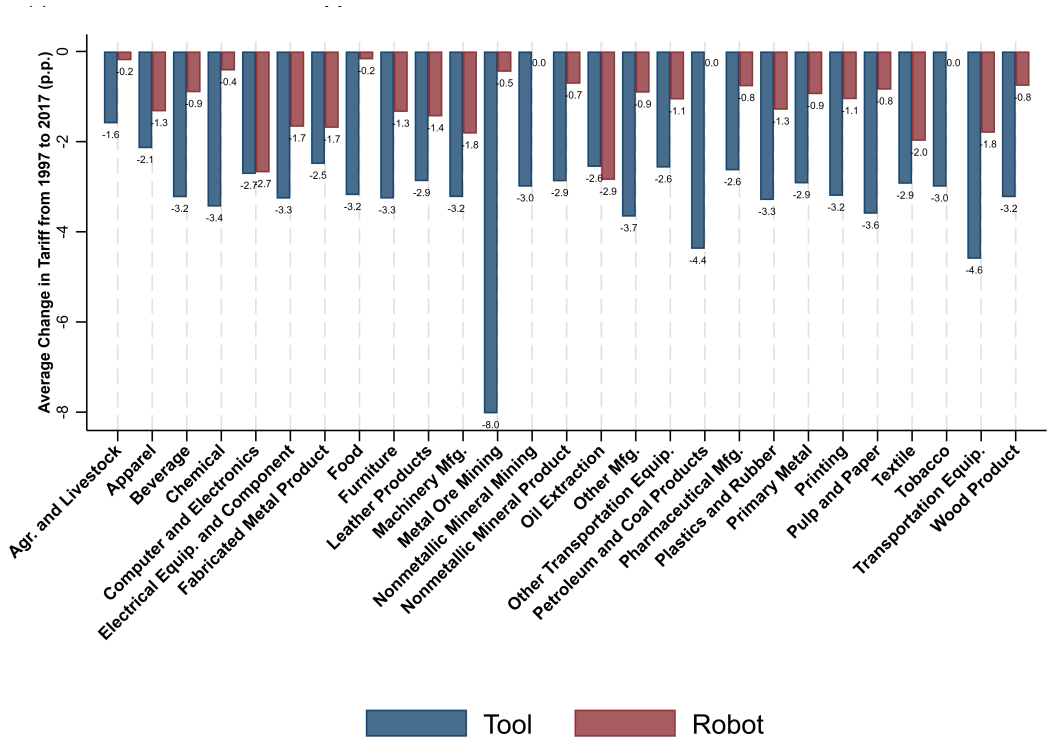
2 Identifying the effect of machines

It is not easy to disentangle the effect of machines on workers' employment and earnings. The problem is that we would like to see what happens with workers when there are more machines and nothing else

is happening in the economy. Then we would be able to see the effect that having more machines has on workers. But, suppose orders for metal parts increase. This is an increase in the demand for the output of metal part manufacturers. Producers may buy more machines and hire more workers in response. A positive association between machinery imports and employment would then combine the effect of the machines with the effect of stronger demand. Likewise, a local labour shortage might encourage automation. How can we separate the effect of machines from the other forces changing employment?

To address this problem, the study does not rely on a direct comparison between machinery imports and employment. Instead, it uses changes in the cost of importing machines. Following negotiations within Mercosur, the South American trade bloc, Brazil cut capital-goods tariffs in the early 2000s. The cuts differed across products. Industries bought different mixes of machines, so they were exposed to different reductions in robot and tool tariffs. Exhibit 1 shows this variation across broad industries. While tariffs on both robots and tools decreased, some industries saw similar decreases (given the types of machines they were importing) while for others tools tariffs decreased much more than robot tariffs.

Exhibit 1. Different industries faced different machinery tariff cuts



Source: de Souza and Li (2025), Figure 1. Average tariff changes, 1997–2014, in percentage points; blue bars refer to tools and red bars to robots. Industry averages reflect the machinery used by each industry.

A lower tariff makes imported equipment cheaper, but its effect on adoption depends on the work being done. A market initially employing many workers in routine activities has greater scope for adopting robots. A market with more work involving hand tools may respond more strongly to cheaper tools. The researchers combine industry tariff changes with these initial differences in *task content* to construct

two measures of *tariff exposure*. The industry tariff measures use the mix of machinery imports from before the reform.

The exposure measures serve as *instruments* for robot and tool adoption. The idea is to use tariff-driven differences in imports, rather than all observed differences in imports, to estimate employment effects. Let Z_R and Z_T denote the robot and tool tariff-exposure measures. The first step uses both measures to predict each kind of import growth:

$$\Delta \log R = \pi_{RR} Z_R + \pi_{RT} Z_T + \text{controls} + v_R,$$
$$\Delta \log T = \pi_{TR} Z_R + \pi_{TT} Z_T + \text{controls} + v_T.$$

Here R and T measure robot and tool imports. Each equation gives a fitted change, $\widehat{\Delta \log R}$ or $\widehat{\Delta \log T}$. The second step relates employment growth to those fitted changes:

$$\Delta \log E = \beta_R \widehat{\Delta \log R} + \beta_T \widehat{\Delta \log T} + \text{controls} + u.$$

Here E is formal employment in an industry–microregion, and changes are taken over five years. This procedure uses the variation in machinery adoption associated with tariff exposure.

To identify the employment effects of machinery, tariff exposure must predict adoption and, after controlling for other forces, affect employment only through robot and tool imports. The researchers control for prior employment growth, initial task composition, tariffs on industries' output and other inputs, common year shocks, and differences across regions and industries. The first-stage estimates show that larger tariff cuts predict more imports of the corresponding machinery. The researchers also find no systematic relationship between tariff exposure and pre-reform employment trends or the other policies they examine.

Both import changes are instrumented in the first column of Exhibit 2. The second column omits tools and uses robot tariff exposure alone to instrument robot imports.

Exhibit 2. Employment estimates with and without tool adoption

	Robots and tools included	Tools omitted
Robot-import coefficient ($\widehat{\beta}_R$)	-0.23^{***}	0.004
Tool-import coefficient ($\widehat{\beta}_T$)	0.17^{***}	—

Source: de Souza and Li (2025), Table 2, column 4, and Table 4, column 4. Both specifications include the controls described above and region, industry, and year fixed effects. *** denotes significance at the 1% level.

With both types of machinery included, the robot estimate is negative and the tool estimate is positive. When tools are omitted, the robot estimate is close to zero and is not statistically significant.

The study also finds that lower robot tariffs encourage tool imports. Firms can therefore respond to cheaper robots by adopting both kinds of machinery, just as in the metalworking example.

Exhibit 3. Employment and earnings across worker groups

Outcome	Robot adoption	Tool adoption
Employment: workers without a high-school diploma	Negative estimate	Positive estimate
Average monthly earnings: workers without a high-school diploma	Negative estimate	Positive estimate
Employment: operational workers	Negative estimate	Positive estimate
Employment: managers and science professionals	No statistically clear effect	No statistically clear effect

Source: de Souza and Li (2025), selected results from Tables 5–6. The positive and negative estimates listed here are statistically significant in the reported specifications. Earnings are monthly group averages; operational workers include workers directly involved in running machinery.

The contrast is particularly visible among workers without a high-school diploma and among operational workers. Average monthly earnings depend on wages, hours worked, and the composition of the employed group.

Question 1. How can we identify the employment effect of machines? (25 marks)

(a) Why would a direct comparison of machinery-import growth and employment growth fail to isolate the effect of machines? Explain how tariff exposure helps and what must be true for it to identify that effect. Using the evidence in the case, assess the credibility of the instruments. [15 marks]

(b) A commentator uses the second column of Exhibit 2 to conclude that robots have no employment effect. Evaluate the claim. [10 marks]

3 A task model of machines and workers

To interpret the findings, consider a production process with tasks $i \in [0, 1]$. Each task supplies a service, such as cutting a component, drilling a hole, or inspecting a finished part. The services combine through equal-weight Cobb–Douglas aggregation:

$$\log Y = \int_0^1 \log y(i)\,\mathrm{d}i, \qquad y(i) = a_K(i)k(i) + a_L(i)\ell(i).$$

Here $k(i)$ and $\ell(i)$ are machine services and labour used at task i, and $a_K(i)$ and $a_L(i)$ are their productivities. Relative labour productivity $a_L(i)/a_K(i)$ increases with i. Let w be the wage and r the rental rate of a machine service. Firms are competitive, so output price P equals minimized unit cost. Firms choose the lowest unit cost at each task. With an interior cutoff I,

$$\frac{a_L(I)}{a_K(I)} = \frac{w}{r}, \qquad \text{machines perform } i < I, \quad \text{workers perform } i > I.$$

Equal expenditure per unit task interval implies

$$wL = (1 - I)PY, \qquad \alpha_L = \frac{wL}{PY} = 1 - I, \qquad \frac{L}{Y} = \frac{(1 - I)P}{w}.$$

Making an available input cheaper or more productive cannot increase minimized unit cost.

Compare two changes, each starting from the same interior assignment:

1. In experiment R, lower tariffs on autonomous machines reduce their rental rate from r_0 to $r_1 < r_0$. The wage and both productivity schedules remain fixed. Experiment R makes it cheaper to use machines that perform tasks on their own.

2. In experiment T, lower tariffs on worker-operated tools allow labour productivity to rise at every task: $a_L(i) \mapsto m a_L(i)$, with $m > 1$. The wage, machine rental rate, and machine productivity remain fixed.

   Experiment T represents better tools: a worker can complete more drilling, grinding, or assembly with the same amount of effort.

Question 2. How do machines and tools change task assignment? (35 marks)

(a) A manager says that a machine should perform every task at which it is more physically productive than a worker. Evaluate the claim. [5 marks]

(b) Compare task assignment in experiments R and T. Illustrate each change with a labelled relative-productivity diagram and explain the rule determining the assignment. Explain how and why the allocation of tasks changes and how it affects the labor share of income. [20 marks]

(c) Do more tasks mean more workers? Hold output fixed. What happens to labour per unit of output and employment in R and T? Explain your answer. [10 marks]

Question 3. Employment across worker groups (15 marks)

Use the task-assignment model to interpret the employment results in Exhibit 3. You may extend it in words to distinguish worker types or apply it separately to groups performing different tasks. State what follows from task reassignment and what requires additional assumptions. [15 marks]

4 When sales respond to lower costs

Now let buyers demand

$$Y = BP^{-\varepsilon}, \qquad B > 0, \quad \varepsilon > 1.$$

Keep B, ε, and w fixed. The rental rate changes only in experiment R. Lower production costs allow firms to reduce their prices and sell more. We can then connect the change in demand with the changes in labor per unit of output:

$$L = Y\left(\frac{L}{Y}\right) \qquad \longrightarrow \qquad \Delta \log L = \Delta \log Y + \Delta \log(L/Y) = (1 - \varepsilon)\Delta \log P + \Delta \log(1 - I).$$

Question 4. Can expanding sales offset labour savings? (25 marks)

(a) Use the expression above to assess the employment effect of experiment T. Explain the contribution of each term. [10 marks]

(b) An analyst claims that elastic demand guarantees higher employment after experiment R. Evaluate the claim and state the condition for employment to rise. [10 marks]

(c) Does experiment T explain the earnings result in Exhibit 3? [5 marks]

References

- de Souza, Gustavo, and Haishi Li (2025). *Robots, Tools, and Jobs: Evidence from Brazilian Labor Markets*. Federal Reserve Bank of Chicago Working Paper 2023-42, May 23 revision.