

The adoption of digital technologies in Brazilian industrial firms: patterns of path dependence and determinant factors

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Introduction

This is an original longitudinal study about the adoption of digital technologies by 299 Brazilian industrial firms, from different sectors and sizes, based on two direct surveys carried out in 2017 and 2019/2020. Firms were questioned about which digital technologies were currently in use and which ones were expected to be adopted in the future (5 to 10 years ahead)¹. This paper has two objectives: (i) to analyse the evolution in the adoption of different generations of digital technologies in time, searching for patterns of path dependence and, (ii) to relate the patterns of path dependence to structural and conduct features of firms.

For that, after a review of the relevant literature, firstly, from the questions posed to firms, a methodological effort was made to develop appropriate indicators to observe current and prospective adoption patterns in each survey, and to proceed to the longitudinal analysis in search of patterns of path dependence.

Secondly, and departing from the descriptive exercise of movements of firms in time, a quantitative exercise will be made to associate patterns of adoption of digital technologies to the different profiles of firms (size, sector, export, capabilities and mobilisation efforts towards digitalisation).

Thirdly, departing from the assumption that digitalisation is positive related to competitiveness, the paper will discuss the results (different patterns of evolution related to different firms' profile) in terms of possible market-structure outcomes.

The empirical approach

The research programme from which this paper is derived, explicitly recognises five characteristics of the rapid rate of progress of digital technologies and the related adoption process by firms which constitute the backbones of the surveys carried out in Brazil in 2017 and 2019-2020²:

- (i) Digital technologies are, at the same time, transversal to all but specific to each firm; questions must be designed to be answered by any industrial firm, regardless the nature of its activities.
- (ii) Digital technologies are adopted across all business functions, from design to production to relations with clients. What matters then is to raise which digital solutions are adopted to carry out different business functions; not the specific technology in itself, such as painting robots or generic ones such as artificial intelligence.

¹ This paper is the by-product of a research programme (I-2027 and I-2030) in progress since 2017 by a group of researchers from the Federal University of Rio de Janeiro, the Campinas State University, and the Fluminense Federal University. See IEL 2018 and Ferraz et al 2019 for outputs of such research programme.

² A similar approach to question firms about the adoption of digital technologies was adopted in Argentina (Albrieu et al 2019) and in Ghana, Vietnam, and Thailand (Kupfer et al 2019)

- (iii) Digital technologies have been around for a while; it is important to consider that firms may adopt state of the arts solutions and/or older technologies and coexist with different solutions; it is necessary to specify “generations” of digital solutions, naturally having as the ultimate reference the most advanced ones.
- (iv) Four generations were specified: stand-alone solutions; solutions that partially integrate business functions; integrated and connected solutions and, a system that intelligently integrates and interconnects a firm in a digital platform. Such very brief description indicates that the evolution along such digital generation ladder is not linear.
- (v) As present and future adoption prospects matter, direct research must rely on perceptions and expectations of qualified representative of firms.

Thus, in both surveys similar questions were posed to firms about the **current** and the **prospective** (5 to 10 years ahead) generations of digital technologies used or to be used in three different business functions (relations with suppliers and clients and in the management of production processes). Four different generations were specified: stand-alone; partial integration; complete and connected integration and, intelligent connected and integrated solutions. Firms were also asked about the type of efforts (*readiness*) they were currently implementing to achieve the digital solutions expected to be adopted in the future (no actions, studying, planning, implementing plans).

In short, both surveys supplied information about four generations of digital technologies being or expected to be in use in three business functions, in two moments of time.

Searching for patterns of path dependence

In search for possible patterns of path dependence in the adoption of digital technologies, in time, three methodological steps were taken:

- To take up the non-linearity of the digital evolution ladder, values for each generation, using a Fibonacci-like sequence, were defined as follows: first generation = 3, second generation = 5, third generation = 8 and, fourth generation = 13.
- In order to collapse the three business functions, mean values were estimated to obtain the level of digitalisation of a firm, for the present and future.
- Firms declaring to have moved forward (advance) and not having moved forward (stagnating) in the current adoption of digital technologies between the first and second survey were then associated with those expecting to move forward (advance) and not to move forward (stagnating) between 2020 and 2030 (second survey).

The emerging patterns of path dependence in the adoption of digital technologies in Brazil reveals (Table 1):

1. A **sustained and positive path dependence** for 20,4% of firms. Firms demonstrated evolution in current adoption between both surveys and expect further advances between 2020 and 2030.
2. A **discontinuous optimist path dependence** for 23,7% of the firms. Firms stagnate in the current adoption of digitalisation between the two surveys, but the group expect to jump ahead in digitalisation in the future to come (2030 vs 2020)
3. A **discontinuous pessimistic path dependence** for 25,4% of firms. This group moved forward in current adoption between 2017 and 2020 but they demonstrate

a negative perspective between current digitalisation levels (2020) and future prospects (2030).

4. A **sustained and negative path dependence** for 30,4% of firms. This group do not demonstrate progress in current adoption of digitalisation between both surveys (2017 vs 2020) and do not expect to move forward in the future (2020 vs 2030).

Table 1 –Patterns of path dependence

		Projected change: current generation in 2020 and prospective generation in 2030		
		Advance	Stagnation	Total
Actual change in current generation (2017/2020)	Advance	20,4%	25,4%	45,8%
	Stagnation	23,7%	30,4%	54,2%
	Total	44,1%	55,9%	100,0%

Source: own elaboration based on I-2027 and I-2030 database

The nexus exercise (to be developed)

These preliminary findings provide the empirical base to categorise firms according to their style of path dependence.

The next step will be to relate these patterns of path dependence to the different profiles of firms. To do so, the paper relies on an ordered logistic regression. These methods are consensually accepted for survey-based data that has ordinal categorical variables. In these models, there is a relative ordering of response values that are known, but the exact distance between them is not. This feature is essential for the present analysis as efforts were made to identify the profile of firms.

For this paper, the dependent variable will be the patterns of path dependence and the independent variables will be: 8 different sectors of origin; size of firms in four ranges, R&D (yes or no), Export (yes or no), a proxy of capabilities (STEM workers to total workers in 4 ranges) and mobilisation efforts to prepare for the future (no actions, studying, planning, implementing plans).

The standard interpretation of an ordered logit coefficient is that for one unit increase in the predictor, the response variable level is expected to change by its respective regression coefficient, in the ordered log-odds scale, while other variables of the model are held constant. Positive coefficients indicate that higher values of the explanatory variable improve the likelihood of a firm being at a higher category of the dependent variable than the current one, whereas negative coefficients indicate that higher values of the explanatory variable increase the likelihood of a firm being in the current or lower category.

Open questions

Current and prospective adoption of digital technologies really follow a path-dependent trend in which the past strongly conditions the expected future?

What determines the firm to be in one of the four possible dependence paths (sustained and positive; discontinuous optimist; discontinuous pessimistic; sustained and negative)?

How to explain advances, paralysis and/or retrocession processes of adopting digital technologies beyond a firms structural feature?

Does path dependency imply irreversibility in the adoption process? What are the analytical and policy implications in terms of market structure and competition?

References

ALBRIEU, R. et al. (2019) *Travesía 4.: hacia la transformación industrial argentina*. INTAL/BID, Buenos Aires. Nota Técnica del BID 1672

FERRAZ, J.C; KUPFER, D.; TORRACCA, J.; BRITTO, J. N. P. Snapshots of a state of flux: how Brazilian industrial firms differ in the adoption of digital technologies and policy implications. *Journal of Economic Policy Reform.*, v.1, p.1 - 18, 2019.

IEL (2018) *Indústria 2027: riscos e oportunidades para o Brasil diante de inovações disruptivas*. IEL, Brasília. www.portaldaindustria.com.br/cni/canais/industria-2027

KUPFER, D.; FERRAZ, J.C.; TORRACCA, J. (2019). *A comparative analysis on digitalization in manufacturing industries in selected developing countries: Firm-level data on Industry 4.0*. Department of Policy, Research and Statistics, UNIDO, Vienna, Working Paper 16/2019.