The Effect of Technological Change on Firm Survival and Growth - Evidence from Technology Standards

Justus Baron*
Northwestern University

Daniel F. Spulber†
Northwestern University

April 21, 2017

Abstract

We analyze the effect of technological change on firm exits, establishment entry and exit, and the creation and destruction of jobs. We make use of a novel measure of technological change: technology standards. Replacements and withdrawals of standards provide information about technological obsolescence, whereas references among standards signal new uses for existing technologies. Relating standards to firm cohorts using the date of publication, we find that the withdrawal of standards induces a significant increase in the rates of firm deaths, establishment exits and job destruction in the firms associated with the replaced standards. New standards building upon existing standards however have the opposite effect, as firms associated with the technological vintage being referenced create new establishments at a higher rate.

JEL-Classification: L15, L16, O33

Keywords: creative destruction, business dynamics, technological change, technology standards

*Corresponding Author. Research Associate, Searle Center on Law, Regulation, and Economic Growth, Northwestern University Law School, 375 East Chicago Avenue, Chicago, IL 60611. E-mail: justus.baron@law.northwestern.edu.

†Elinor Hobbs Distinguished Professor of International Business, Department of Strategy, Kellogg School of Management, Northwestern University, 2001 Sheridan Road, Evanston, IL, 60208, and Research Director, Searle Center on Law, Regulation, and Economic Growth, Northwestern University Law School, Chicago, IL. E-mail: jems@kellogg.northwestern.edu.

1 Introduction

Technological change has long been recognized as an important driver of economic growth (Solow, 1957). Business dynamics, including the entry and exit of firms, and the reallocation of labor through the creation and destruction of jobs in different firms, are another important driver of economic growth (Jovanovic, 1982). In many models of economic growth going back to Schumpeter (1934), technological change and business dynamics are inter-dependent. In modern Schumpeterian growth theory (Aghion and Howitt, 1992; Klette and Kortum, 2004) new entrepreneurial firms are the vehicle through which new technologies enter the market. This technological change produces a creative destruction of incumbent firms, thus allowing production factors to be reallocated to the most efficient technology embedded in the new firms (Caballero and Hammour, 1996). The theory thus predicts a very close correlation between technological change and business dynamics.

The hypothesis of a particularly close relationship between technological change and the entry, growth and exit of firms underlies the literature on vintage capital (Caballero and Hammour, 1994; Campbell, 1998). In this literature, technology is embedded in different vintages of capital. Firms' marginal cost of adoption increases with age, so that firms' technological choices remain associated with the technology that was state of the art when they were created (Jovanovic and Lach, 1989). For a firm, changing the vintage of capital is costly, and firms are thus more likely to exit when new, sufficiently superior technologies are introduced by new entrants (Campbell, 1998). In addition, managers may decide to close a firm and create a new one in response to technological change (Jovanovic and Nyarko, 1996). These theories have important general equilibrium implications for economic growth and short term fluctuations (Samaniego, 2010).

In spite of these important implications for the analysis of economic growth, large-scale empirical evidence on the relationship between business dynamics and technological change is scarce. This can largely be attributed to the dearth of available measures of technological change across industries and technological fields. In this article, we introduce data on technology standards as a direct measure of an industry-wide technological change contributing to the obsolescence of some vintages of technology, while expanding the use of other vintages. Technology standards offer a wealth of detailed information on aggregate technological change. In particular, version histories of standards provide information on technological replacements; whereas references among standards indicate that an existing standardized technology is implemented in another, new standardized technology. Data on technology standards thus provide information on the rate and direction of technological change.

We use the Searle Center Database on Technology Standards (Baron and Spulber, 2016) in conjunction with the Business Dynamics Statistics (BDS) based on the Longitudinal Business Database (LBD) of the US Census Bureau (Jarmin and Miranda, 2002). We analyze whether growth, decline and survival of firms is correlated with the technological evolution of the standards that were developed around the same year in which the firms were created. We thus directly test the hypothesis that firms enter an industry based on the latest available technology, and that the exit of these firms coincides with the replacement of the technology vintage that they use. We find that such vintage-specific technological change, as indicated by technology standards, can contribute to explain aggregate business dynamics. In particular, the exit rate of firms increases in the rate at which standards developed in the year of their creation are being replaced, whereas the rate at which firms create new jobs or new establishments increases in the rate at which new standards reference the standards that were developed in the year of firm creation.

Our findings provide support for the prediction that the survival and growth of firms depends on the continued and expanded use of the technology vintage that was new at the time when the firm was created. This effect is disproportionately driven by larger firms with more than 100 employees. While smaller firms may adjust to technological change, larger firms may face more substantial costs when reversing fundamental technological choices embedded in the firm.

One of the main contributions of our research is the use of a novel, direct indicator of technological change. Technology standards data promise to provide a major new source of information for the empirical economic analysis of innovative activity. Griliches (1990) once observed that there are almost no good measures of technical and scientific progress: "In this desert of data, patent statistics loom up as a mirage of wonderful plentitude and objectivity." Our paper shows that data on technology standards open up another important, yet widely unrecognized window on technological change and its relationship with economic variables.

2 Related literature

2.1 Analyses of economic growth, firm entry and exit and technological change

In the macroeconomic literature, the relationship between technological change and business dynamics is particularly crucial to Schumpeterian Growth theory (Grossman and Helpman, 1991; Aghion and Howitt, 1992).[1] In these models, entrepreneurial firms enter the market based on novel technologies. When new firms offering new products or practicing new production processes acquire larger market shares, they produce an aggregate technological change in the economy. In a process of creative destruction, the incumbent firms based on older, less efficient technology are out-competed by the new firms and shrink or exit the market. Entry and exit of firms, or more generally the reallocation of production factors from old to new firms, is thus a key vehicle of technological change. Campbell (1998) proposes a growth model with creative destruction, in which new technologies are embedded in new plants, and corroborates the theoretical analysis by analyzing the dynamics between census data and the entry and exit of establishments and rates of economic growth.

In other growth models, innovations are also carried out by incumbent firms, which can improve their own products or processes (Lucas and Moll, 2014). In addition, both entrants and incumbents can innovate by offering entirely new varieties, that don't compete with the products offered by incumbent firms (Romer, 1990). Klette and Kortum (2004) propose a Schumpeterian model of growth with innovation by incumbents and entrants,

[1]see (Aghion et al., 2014) for a survey

which can account for empirically observable firm dynamics. Empirical research based on business dynamics statistics suggests that own-product improvements could constitute the most important source of growth, dominating the effects of new varieties or creative destruction (Garcia-Macia et al., 2016). Nevertheless, creative destruction is also found to be a significant driver of growth, and firm births contribute significantly to gross and net job creation in the economy (Haltiwanger et al., 2013).

2.2 The empirical analysis of business dynamics

Dynamics of firm survival and growth have been studied by an extensive literature in industrial organization. A large number of theoretical and empirical research investigates and analyzes empirical regularities, such as Gibrat's law about the independence of firm size and growth. According to Sutton (1997), "the focus of interest in all these studies lies in estimating (a) the probability of survival of a firm, conditional on its age, size, and other characteristics, and (b) the probability distribution describing the firm's growth rate conditional on survival, and its dependency on age, size, and other characteristics."

The empirical literature on firm productivity documents that a large portion of aggregate productivity growth in specific industries is attributable to the reallocation of resources to more productive firms (see Bartelsman and Doms (2000) for a review of studies using longitudinal micro-data). Olley and Pakes (1996) analyze productivity growth and firm entry and exit in the telecommunication industry after deregulation. They find that most of the productivity growth induced by deregulation in the industry has arisen from resource reallocation, in particular through the exit of low productivity plants. More recently, Asplund and Nocke (2006) study business dynamics in the Swedish hair salon industry. Foster et al. (2006) analyze the US retail sector. They find that "virtually all of the labor productivity growth in the retail trade sector is accounted for by more productive entering establishments displacing much less productive exiting establishments". Nevertheless, a substantial share of this resource reallocation occurs between different establishments of the same firm.

In addition, there is a growing literature studying aggregate business dynamics in the economy, and analyzing the interaction between firm entry and exit, resource reallocation among firms and the business cycle. Moscarini and Postel-Vinay (2012) study job creation and destruction by small and large firms over the business cycle. Reallocation of resources among firms over the business cycle can be induced e.g. by firms' different roles in the labor market, or their relative advantages or disadvantages in the access to finance.

2.3 Empirical studies of business dynamics and technological change

A number of empirical studies directly analyzed the relationship between business dynamics and technological change.[2]

[2]On the level of single products, several empirical studies have analyzed the relationship between technological innovation and firm dynamics in so-called industry life-cycles (Agarwal and Gort, 1996; Klepper,

There is contrasted firm-level evidence on the relationship between firm dynamics and technology usage. Dunne (1994) finds that, after controlling for plant size, technology usage was found not to be correlated with age. This finding is in contradiction with the predictions of the literature on vintage capital, which stipulates that younger firms use more innovative technology. Doms et al. (1995) find that capital-intensive plants and plants employing advanced technology have higher growth rates and are less likely to fail. Foster et al. (2006) find that establishments having higher capital per worker and computer investment intensity are more productive and less likely to exit than other establishments.

In addition to technology usage, firm dynamics can be related to firms' participation in inventive activities. Several recent papers (Akcigit and Kerr, 2015; Graham et al., 2015) match the US census data to the USPTO database. Graham et al. (2015) find that young firms are more likely to patent than older firms. Akcigit and Kerr (2015) compare the patenting activitis of entrants and incumbents. Incumbent firms are more likely to improve upon their prior inventions, while entrants are more likely to produce breakthrough inventions.

While the firm-level evidence is informative, it is unlikely to capture the full dimension of the relationship between business dynamics and technological change. Clearly, a firm's survival and growth can be impacted by technological change even if the firm does not engage in inventive activities or patenting. Only a small proportion of firms apply for patents. Graham et al. (2015) find that less than 1% of US firms were granted a patent between 2001 and 2011. While these firms are larger on average than other firms, patenting firms only account for 33% of employment in the US economy. While usage of technology is more broadly distributed in the economy, a firm's productivity can also be associated with a technological vintage if the firm itself is not using the associated technology. For a firm to be impacted by technological change, it is sufficient that a firm's viability is determined by an aggregate industry structure which is determined by the technological state of the art.

The firm-level evidence is thus complemented by evidence on the industry level. Samaniego (2010) analyzes the relationship between industry entry and exit rates and the pace of technical progress in the capital goods that the industry uses. The author finds that "a significant fraction of entry and exit thus represents the introduction and replacement of capital-embodied technologies." The empirical analysis in Samaniego (2010) builds on a model in which new technologies are implemented by new firms; leading to a direct relationship between a firm's productivity and the state of the art at the time of its creation.

1996; Klepper and Simons, 2000). These studies analyze the patterns of entry, growth and exit among firms in an industry producing a new product. This literature has revealed that many industries are characterized by significant entry in the early stage, followed by a "shake-out", i.e. exit of a large share of the firms, while other firms grow, as the industry advances to maturity.

3 Technology standards as a measure of technological change

3.1 Empirical measures of technological change

A number of direct and indirect measures of technological change are commonly used in research on economic dynamics. Examples include the quality-adjusted relative price of capital used in each industry (Samaniego, 2010) or unexplained residuals in TFP growth (Galí, 1999). These measures have the advantage of being available for the aggregate economy; but they constitute a black box on the underlying technology. The measurement of technology rests on underlying assumptions about the economic effects of technology.

The most common alternative to these indirect measures is data about patents (Acemoglu et al., 2016). Patents are a great source of information: they span large sectors of technological change (even though many components of technological change are unlikely to be patented), and provide potential for rich micro-based analyses of the processes of technological change (firm level, citations, renewals). Akcigit and Kerr (2015) e.g. use patent citation analysis to decompose innovation in invention of new products and improvements of existing products. Nevertheless, patents have shortcomings. Patents measure inventions, and inventions translate into innovation with very different time-lags. The economic value of patents is highly heterogeneous, and most patents are never practiced. Propensity to patent is strategically determined on the firm level.

Alexopoulos (2011) introduces technology manuals as a measure of technological change. This measure also spans very large sectors of technological change, and temporally coincides with technology adoption. Nevertheless, it provides less potential for investigating channels and processes of technological change. Indeed, the publication of technology manuals is a symptom of change, rather than a measure of a component of change itself.

Baron and Schmidt (2016) introduce technology standards as a measure of technological change. Adoption of new ICT standards translates into TFP gains on the long run, even though TFP declines on the short run. This is indicative of disruptive technological change. Consistent with this hypothesis, Baron and Schmidt (2016) find that only fundamentally new standards induce a short run contraction in TFP, while incremental improvements of standards immediately translate into TFP gains (even though on the long run lower than those induced by new standards). Forward-looking variables, like investment and stock market prices, react positively to technological change upon impact. The use of technology standards as a measure of news about future productivity gains is further explored and validated by Kurmann and Sims (2017).

3.2 The promise of technology standards as an indicator for economic research

Technology standards bear a significant promise for the economic analysis of technological change. Quantitative data on technology standards is plentiful, and has many desirable characteristics of an indicator of technological change for the purpose of economic research.

First, technology standards are ubiquitous. In highly industrialized and interdependent economies, there is hardly an industry that does not extensively rely on standards and technical protocols. The production of complex products (e.g. cars, airplanes, computers) requires standards, so that the numerous components, which are often produced by many different firms, seamlessly work together.[3] Many industries are subject to network effects (e.g. telecommunications, transportation, logistics, finance), and require compatibility standards so that consumers can enjoy the benefits of larger networks.[4] Quality standards are essential for consumers and manufacturers purchasing goods whose quality is difficult to observe (e.g. materials, chemicals, drugs). For firms to work together efficiently, potential employees to be operational in different firms, or knowledge to accumulate in the economy, many processes within firms are highly standardized (e.g. accounting, human resources, IT).[5] A very large share of the economy is thus subject to standards, and changes in standards can describe a large variety of processes of technological change in the economy.

Second, technology standards are numerous. Standard Setting Organizations (SSOs) produce a large number of technology standards: one data base lists 1,400,000 standards and technical specifications. These standards are produced by an astonishing diversity of SSOs. One website currently lists over 1,000 SSOs for the area of Information and Communication Technologies alone. Some of these SSOs are very large organizations, with thousands of member companies. Large firms are often members of several hundred SSOs.[6] Data on technology standards and SSOs thus provide thick information that can be used for quantitative research.

Third, technology standards are economically meaningful and important. While many inventions, including patented inventions, are rarely or never used, technology standards emerge from a consensus decision of large groups of firms, often entire industries (Goerke and Holler, 1995; Simcoe, 2012; Bonatti and Rantakari, 2016; Spulber, 2016). For many products, compliance with a standard may be an essential determinant of the value of the product. For many technologies, inclusion into a standard may be an essential determinant of use.[7] Technology standards can thus significantly determine competition in the product and technology market (Besen and Farrell, 1994). Harmonization of standards between countries is an important determinant of international trade (Clougherty and Grajek, 2014). Standards are thus important for economic research.

Fourth, technology standards are endogenously determined, reflecting underlying technological change and also promoting technological change (Spulber, 2013). Revisions in standards respond to technological change (Baron et al., 2016).[8] Standards can be broadly

[3] A conservative estimate is that there are 200 standards implemented in a regular laptop computer (Biddle et al., 2010).

[4] Effect of rail gauge standardization, the box

[5] a particularly telling example is the progressive standardization of medicine

[6] In a sample of 200 SSOs and consortia, Baron and Spulber (2016) find that IBM is or has been a member of at least 95 organizations. This represents only a subset of the larger universe of SSOs.

[7] Rysman and Simcoe (2008) find that inclusion of a patented technology into a standard increases the patent's value. In a significant body of case law and legal literature, the value of a standard-essential patent for a standard-compliant product is decomposed into the patented technology's intrinsic value, and the value accruing from standardization (see Pentheroudakis and Baron (2017) for an overview).

[8] ISO e.g. states: "ISO standards represent, by an international consensus among experts in the technology concerned, the state of the art. To ensure that ISO standards retain this lead, they are reviewed at least every five years after their publication. The technical experts then decide whether the standard is still

divided into two categories: performance and interoperability. Innovations that improve the performance of various technologies are likely to cause revisions of performance standards. For example, improvements in the energy efficiency of electrical appliances drive increases in energy efficiency standards. Innovations that result in new products or components are likely to result in new types of technology standards and new interoperability requirements. For example, increases in transmission speeds in mobile communications generate new standards for mobile phones and new types of interoperability among components.

Because technological change is a driver of technology standards, the issuance of new standards and the revision or withdrawal of existing standards by SSOs offer meaningful economic information about the rate and direction of technological change. Growth in the number of technology standards, and information about changes to existing standards, provide useful economic information that cannot be obtained through such measures as R&D investment, patent counts, technology surveys, or direct measures of changes in Total Factor Productivity (TFP).

Fifth, technology standards provide rich quantifiable information. The source of quantitative technology standards data is the set of characteristics of technology standards documents. Technology standards can be informal agreements or mere conventions (so-called de facto standards), but many standards are codified in formal documents issued by SSOs according to specified procedures. These documents often consist of highly complex technical specifications for parts, components and products assuring performance quality and interoperability. Examples are Internet Protocol, WiFi, and 4G (LTE). Technology standards refer both to individual documents and to technology platforms consisting of many documents.

Technology standard documents yield a variety of statistics.

(1) The number of documents themselves provides economic information. Standard documents have a known publication date, and different sources provide information about standard withdrawal rates. It is thus possible to count numbers of new standards, and to measure stocks of active standards.

(2) The lifetime of technology standards provides information about incremental and drastic innovations. Standards undergo amendments, revisions and replacements (half of the standards are revised or withdrawn within 15 years after release). Version histories of technology standards indicate cumulative technological progress, whereas replacements of technology standards provide indicators of technological change (Baron et al., 2016; Baron and Schmidt, 2016).

(3) Connections among technological standards provide further information about the nature of technological change. Technology standards make normative or informative references to other standards. Normative references indicate that complying with the referenced standard is necessary for compliance with the referencing standard, whereas informative references indicate that complying with the referenced standard is useful for compliance with the referencing standard. References of new standards to existing standards indicate that there are new technical methods or products making use of an existing

valid, or whether it should be withdrawn or updated. In some fields, the pace of development is such that when an ISO standard is published, the experts who developed it are already thinking about the next version!" (http://www.iso.org/iso/home/faqs/faqs standards.htm, last consulted in May 2015) technology. References thus provide information about the direction of technological change.

(4) Technology standards can have multiple industry codes in the International Classification of Standards (ICS) that indicate the industries to which the standards apply and also can be combined to consider the scope and importance of the technology standard. This classification is analogous to patent classifications by United States Patent and Trademark Office (USPTO) categories or Cooperative Patent Classification (CPC) codes. Furthermore, standards can be issued by SSOs that are national or international in scope and outreach. Technology standards can thus indicate technological change by technological field, and by country.

The following table provides a comparison of patents and standards as indicators of technological change for economic research.

	Patents	Technology standards
1. Measures	Single technology	Multiple technologies
2. Characteristics	Intellectual property	Common rules
3. Technological change	Invention	Innovation
4. Aggregation	Inventor	Industry
5. Content	Claims	Performance and interoperability specifications
6. References	Other patents	Other standards, Standard Essential Patents (SEPs)
7. Organization	Government patent offices	Private SSOs
8. Geographic scope	National	National, regional, and international
9. Timing	Granting patent	Adoption and revision of standard
10. Strategic behavior	Patent owner	Industry

Table 1: Overview over patents and technology standards as indicator of technological change

3.3 The Searle Center Database

The Searle Center Database of Technology Standards and SSOs (Baron and Spulber, 2016) is the first comprehensive source of empirical data on standards and standardization for economic research. To be sure, other databases have existed before. In particular, PERINORM has been fruitfully used in economic research (Swann et al., 2005). Nevertheless, PERINORM and other databases are limited in scope, and not designed for economic research.

The Searle Center Database incorporates information from a variety of sources, including PERINORM, the IHS Standards Store, Document Center, and the website of several SSOs. It is focused on US and international SSOs, and extends its coverage to hundreds of smaller or informal SSOs and consortia not covered by other databases. As a result of these extensions, it includes 797,711 standard documents issued by 615 US-based or international SSOs. The data spans a large variety of technological fields. In addition to bibliographic information like publication and withdrawal dates, the database includes data-sets with version histories, and almost 4 million standard references linked to both the referencing and referenced document.

Many, but not all standards documents can be assigned to a technological field using a standardized classification scheme, the International Classification of Standards (ICS). Baron and Schmidt (2016) identify ICT standards as standards classified into the ICS classifications 33 (telecommunications) and 35 (information technology), as well as standards issued by SSOs with an exclusive or very predominant focus on ICT.[9] For the period from 1975 to 2014, more than 15% of the standards documents in the database are thus identified as ICT standards. As shown in Figure 1, both the number of standard documents published every year, and the share of ICT standards in the population of new standards are steadily increasing over time.

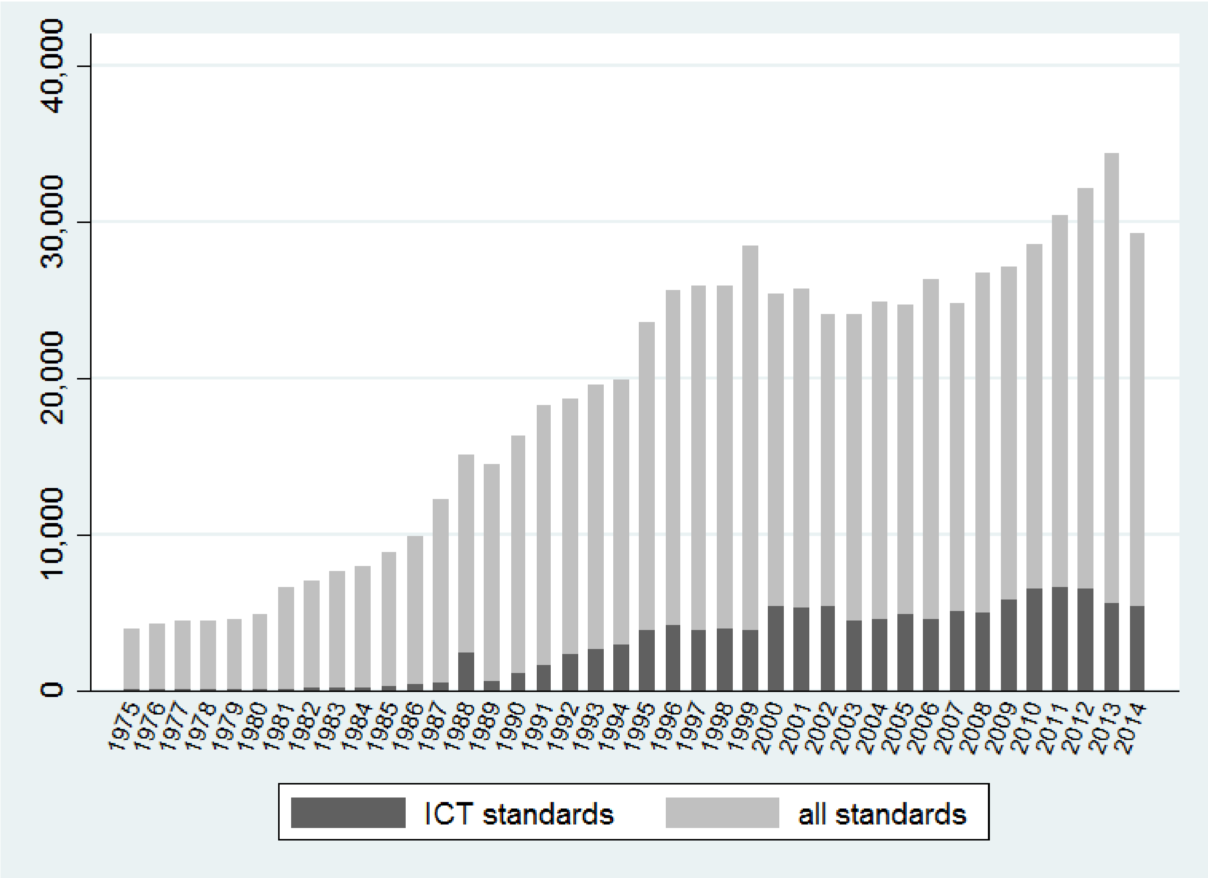


Figure 1: Number of standard documents in the Searle Center database, by publication year)

4 Analytical framework

Let N_t be the number of firms at date t. There are different *cohorts* of firms, which are firms created in the same year. In order to simplify, we consider representative firms for each cohort.

[9]Only the standards of formal SSOs are classified into the ICS classification system. We use the ICS system whenever available, and classify standards based on the technological focus of the SSO in the case of less formal SSOs.

$$N_t = \underbrace{N_{t,\theta=t}}_{\text{entrants}} + \underbrace{\sum_{\theta=1}^{t-1} N_{t,\theta}}_{\text{incumbents}}$$

The number of firms changes as a result of entry and exit.

$$N_t = N_{t-1} + N_{t,\theta=t} - \sum_{\theta=1}^{t-1} \tilde{N}_{t,\theta} \quad \text{where } 0 \leqslant \tilde{N}_{t,\theta} \leqslant N_{t-1,\theta}$$

Let S_t denote the technology in the industry at date t, which is a composite of the technologies $s_{\theta,t}$ used by firm cohorts θ. The representative firms of different cohorts use different technologies, reflecting technological choices made at entry or early in the firm life that are difficult or impossible to reverse at greater firm age.

Technological change may be continuous or discontinuous. Discontinuous technological change only affects the technology of entrants and future cohorts of entrants. Continuous technological change may affect all firms, or only some cohorts of firms. Discontinuous technological change represents innovations that are sufficiently incompatible with existing physical, human or organizational capital, so that incumbents don't adopt the new technology. Continuous technological change represents innovations that can be profitably adopted by at least some incumbents.

As a result of continuous technological change, $s_{\theta,t} \geqslant s_{\theta,t-1}$. As a result of discontinuous technological change, $s_{\theta=t,t} \geqslant s_{\theta=t-1,t}$.

$\Pi(X_{\theta,t}, N_t, S_t, s_{\theta,t})$ is profit or value added of the firm.

We can thus write the entry or survival condition:

$$\Pi(X_{\theta,t}, N_t, S_t, s_{\theta,t}) = 0 \tag{1}$$

A firm's entry and exit decisions depend on its relative technological advantage $s^*_{\theta,t}(s_{\theta,t}, S_t)$, which may increase or decrease as a result of technological change (an incumbent's relative technological advantage can only decrease as a result of discontinuous technological change).

Let X be the key input, say labor.

Profit maximization implies:

$$\delta\Pi(X_{\theta,t}, N_t, S_t, s_{\theta,t})/\delta X_\theta = 0 \tag{2}$$

A firm's size (number of employees or establishments) increases in $s^*_{\theta,t}$.

Together, we can solve for $X_{\theta,t}(S_t, s_{\theta,t})$ and N_t, and also value added per firm $\Pi(X_{\theta,t}, N_t, S_t, s_{\theta,t}) = \Pi(X_{\theta,t}(S_t, s_{\theta,t}), N_t(S_t), S_t, s_{\theta,t})$

We can write GDP as:

$$Y_t = \sum_{\theta=1}^{t} N_{\theta,t}(S_t, s_{\theta,t})\Pi_{\theta,t}(S_t, s_{\theta,t}) \tag{3}$$

Hence, economic growth can be written as:

$$\delta Y_t/\delta t = \underbrace{N'(S)\Pi(S)\delta S/\delta t}_{\text{firm number effect}} + \underbrace{N(S)\Pi'(S)\delta S/\delta t}_{\text{firm size effect}} \tag{4}$$

$$\delta Y_t/\delta t = \underbrace{N_{\theta=t}(S,s)\Pi_{\theta=t}(S,s)\delta S/\delta t}_{\text{entry effect}} - \underbrace{\sum_{\theta=1}^{t-1} \tilde{N}_\theta(S,s)\Pi_\theta(S,s)\delta S/\delta t}_{\text{exit effect}} + \underbrace{\sum_{\theta=1}^{t-1} N_\theta(S,s))\Pi'_\theta(S,s)\delta S/\delta t}_{\text{survivor size effect}} \tag{5}$$

We can thus decompose variations in economic output into firm entry, exit and the change in the size of surviving incumbents. Each of these three components depends on technological change $\delta S/\delta t$. As S_t is a composite of the technologies used by different firms at time t, $\delta S_t/\delta t$ is a composite of the technological change affecting different cohorts of firms (i.e. changes in the technology used by incumbents, and the relative technological advantage of entrants with respect to incumbents). This can be rewritten as a composite of a general technological change (producing the same effect on all firms), a relative technological change (affecting the distribution of relative technological advantages of the different cohorts of incumbents), and discontinuous technological change (affecting the relative technological advantage of entrants).

$$\delta S_t/\delta t = \begin{pmatrix} \delta s_{\theta=1,t}/\delta t \\ \delta s_{\theta=2,t}/\delta t \\ \ldots \\ \delta s_{\theta=t-1,t}/\delta t \\ s^*_{\theta=t,t} \end{pmatrix} = \begin{pmatrix} \delta \bar{S}/\delta t \\ \delta s^*_{\theta=1,t}/\delta t \\ \delta s^*_{\theta=2,t}/\delta t \\ \ldots \\ \delta s^*_{\theta=t-1,t}/\delta t \\ s^*_{\theta=t,t} \end{pmatrix} \tag{6}$$

Traditional Schumpeterian growth theory studies the relationship between discontinuous technological change embedded in entrant firms ($s^*_{\theta=t,t}$) and the entry and exit of firms. Several analyses allow for contemporaneous and potentially offsetting effects of discontinuous technological change $s^*_{\theta=t,t}$ and productivity increases over age $t-\theta$ (Campbell, 1998; Jensen et al., 2001). Finally, Samaniego (2010) studies the effect of general technological change $\delta \bar{S}/\delta t$. By contrast, we focus on technological change that differently affects different vintages of existing technology, and study the effect of the rate of *relative* technological change $\delta s^*_{\theta \neq t,t}/\delta t$ on the survival and growth of different cohorts of incumbents. We define $\phi_{t,\theta}$ as the relative technological change acting on firm cohort θ in the interval from $t-1$ to t.

5 Empirical analysis

5.1 Methodology

From the longitudinal business dynamics statistics, we obtain for each year from 1977 to 2015 the following *rates* for the US economy: firm death rate, establishment exit rate, job destruction rate, establishment entry rate, job creation rate, and net job creation rate. Rates are calculated respectively as percentages of the number of active firms, active establishments, and number of jobs at the beginning of year t. The firm death rate, establishment exit rate, and job destruction rate are thus bound to be between 0 and 1, whereas the establishment entry rate and job creation rate are bound to be non-negative, and the net job creation rate can be any rational number.

For each year, the LBD statistics provide these rates for all US companies, aggregated by age categories. Age categories identify the exact age in number of years up to 5 years, followed by intervals from 6 to 10, 11 to 15, 16 to 20, and 21 to 25 years. We exclude firms that are older than 25 years. The census begins to track these firms in 1977, so that the data is left-censored (only young firms are observable in the earliest years of the sample period). For each year t, we can thus observe the firms of an age group $t-\theta$ exit, open or close establishments, and create or destroy jobs (where θ is the year or the five-year period in which the firms in this group were created).

From the Searle Center Database, we construct a census of standards mirroring the US census of firms. The database includes standards issued by US and international SSOs in a large variety of technological fields. For each year t, we identify the number of standards active at the beginning of the year (all standard documents with a release date before, and a withdrawal date after the beginning of the year; and all standard documents with a release date before the beginning of the year which are currently still active). We categorize active standard documents into the same age categories used in the US census LBD, based on the publication date of the document. A standard document that in year t is in the same age category $t-\theta$ as a firm in the census data was thus released in the same or approximately the same year θ in which the firm was created. To compute the standard withdrawal rate and the standard reference rate, we respectively divide the number of standards withdrawn during year t and the number of new standard references to existing standards by the number of active standards within each age category.[10]

We model the rate of firm death, establishment entry and exit, and job creation and destruction as a function of firm age, a time effect common to all incumbent firms, the

[10]We thus calculate the *percentage* of standards of a certain age group that are withdrawn in year t, and the number of new references to existing standards in a certain age group divided by the number of active standards in that age group. We only include *new* references, i.e. standard documents adopted in year t which reference a specific standard for the first time. A new standard version of an existing standard repeating a reference already made in a previous version will thus not be counted as a new reference. As a robustness check, we computed all results using the overall rate of references instead of the rate of new references, and the results are qualitatively and quantitatively similar.

cohort-specific effect of technological change $\phi_{\theta,t}$, and an error term. The common time effect captures general technological change $\delta\bar{S}/\delta t$ as well as the relative technological advantage of new entrants over incumbents $s^*_{\theta=t,t}$. In addition, the time effect captures non-technological factors affecting all cohorts of firms, and in particular the business cycle, conditions in the labor market, access to finance, and political factors that affect survival, growth and employment in all firms independently of their age. General technological change and discontinuous change affecting only new entrants are thus not separately identified from non-technological factors. The error term accounts for any time-variant factor other than technological change that differently affects firms of different age, e.g. access to finance or labor. For simplicity, and to allow the same model to apply for the different rates, we opt for a linear model. We use the most flexible specification of firm age and common time effects possible with the data by including a full set of year and age category dummies.

$$\rho_{t,\theta} = \beta_1 T + \beta_2 AGE + \beta_3 \phi_{t,\theta} + \epsilon_{t,\theta} \tag{7}$$

The rate of cohort-specific technological change $\phi_{\theta,t}$ is not directly observable. We do however observe rates of changes to standards, $\kappa_{t,\theta}$, and assume that a technological change that renders a technological vintage obsolete positively affects the rate at which standards of this vintage are replaced, whereas a technological change creating new applications and usage for a technological vintage positively affects the rate at which standards of this vintage are referenced. In addition, similar to firms, rates of changes affecting standards are a function of age, common year effects and idiosyncratic shocks.

$$\kappa_{t,\theta} = \gamma_1 T + \gamma_2 AGE + \gamma_3 \phi_{t,\theta} + \hat{\epsilon}_{t,\theta} \tag{8}$$

We can therefore estimate the empirical model

$$\rho_{t,\theta} = \delta_1 T + \delta_2 AGE + \delta_3 \kappa_{t,\theta} + \overline{\epsilon}_{t,\theta} \tag{9}$$

where $\delta_1 = \beta_1 + \beta_3\gamma_1$, $\delta_2 = \beta_2 + \beta_3\gamma_2$, $\delta_3 = \beta_3\gamma_3$, and $\overline{\epsilon} = \beta_3\hat{\epsilon}\epsilon$. δ_3 thus measures the sign of the effect of technological change as long as γ_3 is positive, as assumed, and $\overline{\epsilon}$ is uncorrelated with ϵ (i.e. idiosyncratic effects other than technological change producing changes in standards do not affect firm survival and growth). Error terms could be correlated if changes in standards directly affect firm survival or growth, or business dynamics produce immediate changes in standards. We cannot rule out the existence of such immediate causal relationships, even though we believe that our hypothesis of standards and firms being jointly determined by technological change is more plausible, especially in the short run. Our results will be biased towards zero if γ_3 is small, i.e. the effect of technological change on standards is small (in which case standards would be a poor measure of technological change).

5.2 Descriptive statistics

We first present some descriptive statistics about firm death and standard withdrawal rates. Figure 2 presents firm death and standard withdrawal rates over age categories. The probability of firm death decreases continuously with age. This finding has been established by a substantial empirical literature going back at least to Evans (1987), and has been proven to be robust over a large number of industries, countries, and time periods. Standard withdrawal rates also decrease with age, even though at a lesser rate. A large theoretical literature explores technological lock-in resulting from the fact that technological choices are increasingly difficult to reverse over time (Arthur, 1989). Nevertheless, we also find an increased standard withdrawal rate at age 5, which is likely to reflect SDOs' policies of periodically considering revisions to their existing standards (Baron et al., 2016). In spite of some general similarities, firm death and standard withdrawal rates thus have a significantly different age profile (i.e. $\beta_2 \neq \gamma_2$).

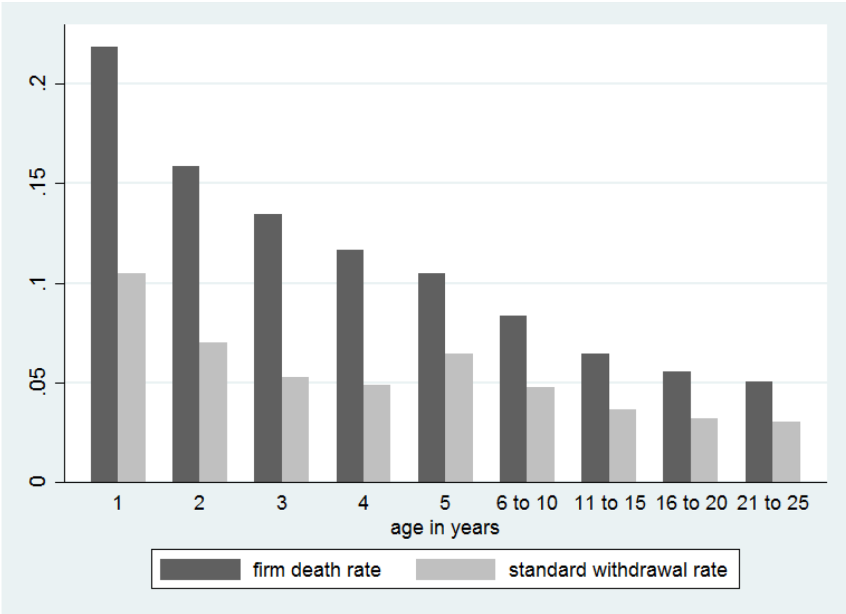


Figure 2: Firm death and standard withdrawal rates over age categories)

Next, Figure 3 compares how firm death and standard withdrawal rates have evolved over time. The firm death rate exhibits cyclical variation (with increases in particular in the 1981 and 2008 recessions), and a slight downward trend. This is consistent with findings by Haltiwanger (2012) and others that firm dynamics and job reallocation in the US have been slowing over the past decades. Standard withdrawal rates on the other hand have been increasing. There is no obvious correlation between firm death and standard withdrawal rates neither at the short or long term. The increase in standard withdrawal rates may reflect increasing rates of technological obsolescence. It is also possible that earlier standard withdrawals are under-reported in the data, because several sources of information on standards are more likely to include standards that are still active or have been withdrawn more recently. Thus, time has a different effect on firm death and standard withdrawal rates (i.e. $\beta_1 \neq \gamma_1$).[11]

[11]Note that a measurement error in γ_1 does not bias the estimate of δ_3 if the under-reporting of earlier standard withdrawals affects all cohorts of standards active at the time when the measurement error

Figure 3: Firm death and standard withdrawal rates over time)

5.3 Standards withdrawal and creative destruction

First, we analyze the relationship between standard withdrawal and firm survival and growth. Following our empirical methodology, we use standard withdrawals as a measure of discontinuous technological change, which differently affects different technological vintages. In Table 2, we present the results of a simple OLS regression of the rates of firm exit, growth and decline over the rate at which standards of the same cohort are withdrawn. We control for the full set of year dummies (not reported) and age category dummies.

We find that within cohorts, there is a strongly significant and positive correlation between standard withdrawal and firm death, establishment exit and job destruction, as well as a negative correlation between standard withdrawal and establishment entry and net job creation. A 1% increase in the standard withdrawal rate is associated with a 0.166% increase in the firm death rate (at 95% confidence, this effect is bound between 0.1395 and 0.1925 %), and a 0.2838% increase in the job destruction rate (between 0.2332 and 0.3344% at 95% confidence).

These findings are a vivid illustration of creative destruction; as we find evidence that technological change is a significant explanatory factor for the destruction of firms, establishments and jobs. More specifically, our findings lend credence to the literature on vintage capital, as the technological change we measure is not common to all firms in the economy, but only to all firms within the same age cohort.

occurred. The under-reporting results from a selection of standards based on survival, not on publication date.

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard withdrawal	0.1660***	0.2838***	0.1354***	-0.0188	-0.3026***	-0.0228
	0.0265	0.0506	0.0228	0.0394	0.0657	0.0172
agecat_0	0.0000	-0.1502***	-0.0753***	0.8637***	1.0139***	1.9438***
	.	0.0060	0.0027	0.0047	0.0078	0.0021
agecat_1	0.2032***	0.1464***	0.1630***	0.1555***	0.0091	-0.0290***
	0.0088	0.0074	0.0033	0.0057	0.0096	0.0025
agecat_2	0.1504***	0.1302***	0.1084***	0.0901***	-0.0401***	0.0006
	0.0087	0.0062	0.0028	0.0048	0.0081	0.0021
agecat_3	0.1288***	0.0978***	0.0853***	0.0671***	-0.0307***	0.0008
	0.0088	0.0057	0.0026	0.0045	0.0075	0.0020
agecat_4	0.1127***	0.0804***	0.0692***	0.0558***	-0.0246***	0.0006
	0.0088	0.0057	0.0026	0.0044	0.0074	0.0019
agecat_5	0.0986***	0.0618***	0.0547***	0.0446***	-0.0172*	0.0001
	0.0087	0.0061	0.0027	0.0047	0.0079	0.0021
agecat_6to10	0.0799***	0.0408***	0.0355***	0.0276***	-0.0132	-0.0003
	0.0088	0.0056	0.0025	0.0044	0.0073	0.0019
agecat_11to15	0.0632***	0.0206***	0.0168***	0.0130**	-0.0076	-0.0008
	0.0089	0.0055	0.0025	0.0043	0.0071	0.0019
agecat_16to20	0.0563***	0.0091	0.0076**	0.0032	-0.0059	-0.0018
	0.0089	0.0056	0.0025	0.0044	0.0073	0.0019
agecat_21to25	0.0519***	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0090	.	.	.	.	.
Constant	0.0521***	0.1515***	0.0938***	0.1369***	-0.0146	0.0404***
	0.0120	0.0135	0.0061	0.0105	0.0176	0.0046
Observations	274	311	311	311	311	311

Table 2: Econometric results: effects of withdrawal rate of technology standards of the same vintage

The results in Table 2 only describe the relationship between firm survival and growth and contemporaneous changes to standards released in the same year (or five-year period) in which the firms were created. The underlying technological change producing changes in firms and standards is unlikely to only last for one year, and may affect firms and standards with different time lags. Also, new firm creations and new standards may incorporate the technological state of the art with different delays or anticipation. It is thus important to study a richer temporal dimension of the relationship between standard and firm dynamics.

We thus estimate a larger set of models with lags and leads of the standard withdrawal rate from 1 to 9 years. We thus observe changes to the *same* standard cohort taking place in years before or after the year in which we analyze the changes to the firms.[12]

$$\rho_{t,\theta} = \delta_1 T + \delta_2 AGE + \delta_3 \kappa_{t+i,\theta} + \bar{\epsilon}_{t,\theta} \quad \text{for } i \in \{-9, \ldots, 9\} \tag{10}$$

[12]Note that we re-compute the age categories for this and the following analyses based on the available standard age in years

In Figure 4, we present the coefficients on standard withdrawal for this set of equations, estimated using OLS regression. We find that firm deaths are uncorrelated with future rates of withdrawal of the same standard cohort. Standard withdrawal rates in earlier years are positively correlated with firm deaths, even though these correlations are measured with bigger confidence intervals, and thus not always statistically significant. This finding may indicate that standard withdrawals *lead* firm deaths, e.g. because standards are replaced more immediately in response to technological change.

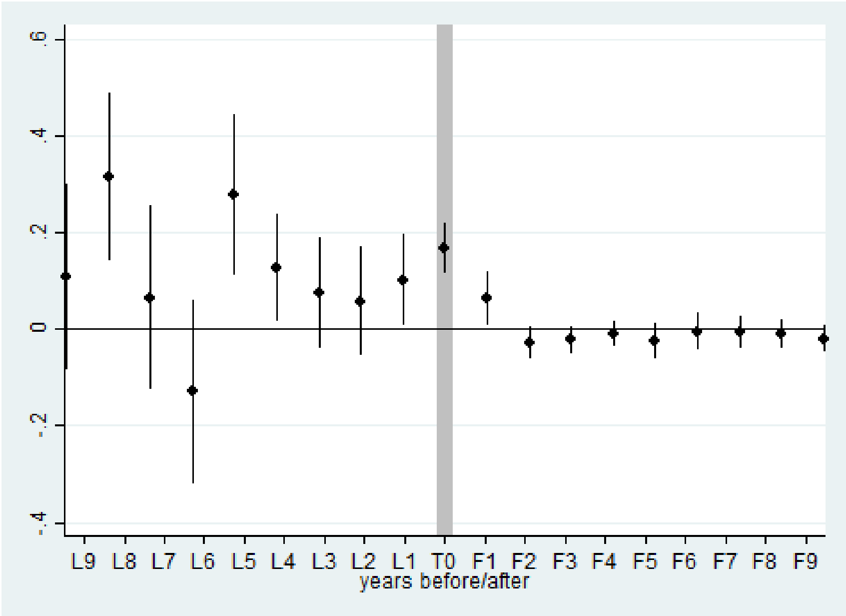


Figure 4: Coefficients and 95% CI effect of standard withdrawal rate on firm death rate (same cohort, lags and leads in years)

Next, we analyze the relationship between the withdrawal rate of a firm cohort and the contemporaneous withdrawal rate of standards released in years before or after the creation of the firm cohort.

$$\rho_{t,\theta} = \delta_1 T + \delta_2 AGE + \delta_3 \kappa_{t,\theta+i} + \bar{\epsilon}_{t,\theta} \quad \text{for } i \in \{-9, \dots, 9\} \tag{11}$$

The results presented in Figure 5 show that firm deaths are uncorrelated with the withdrawal rate of standards that are older than the firm cohort. Firm deaths are however correlated with the withdrawal rate of standards that were released in the first years after firm creation. This finding is consistent with the literature on vintage capital, which stipulates that firms have age-specific marginal costs of technology adoption. Many empirical studies of firm dynamics have revealed that young firms grow quickly, and exit at a high rate. These young firms can thus more flexibly incorporate brand-new technology than older incumbent firms. Alternatively, this finding may indicate that firm creations are more forward-looking than standard releases, and thus anticipate future technological change.

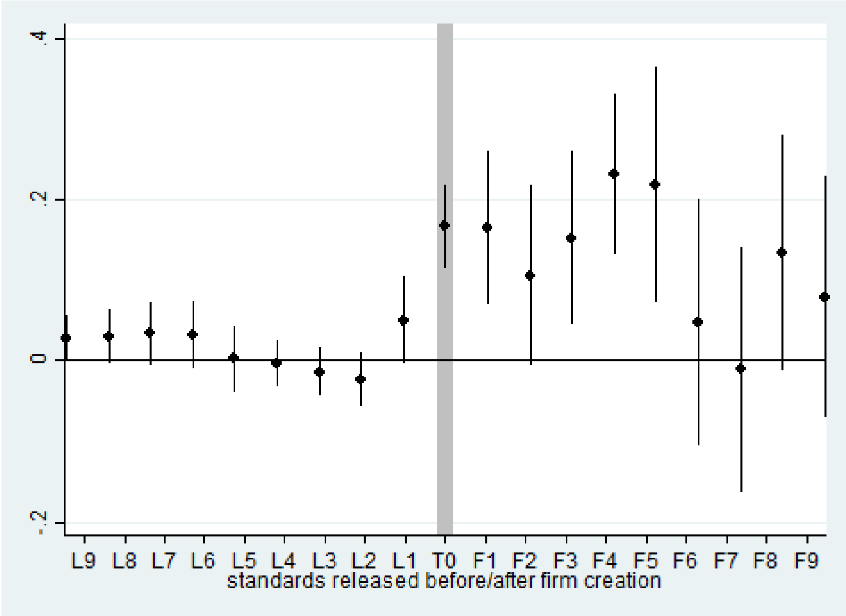


Figure 5: Coefficients and 95% CI effect of standard withdrawal rate of standard cohorts released before/after firm creation (in years) on firm death rate

5.4 Standard references and incumbent growth

Technological change is not necessarily destructive for the incumbent technology and the firms that are associated with it. Technological change can open new opportunities, and create new uses for existing products or new products incorporating existing technology. While technological change may thus annihilate the value of some technological vintages, it can increase the value of others. We use standard references to measure this value-enhancing effects of technological change. As described above, standard references indicate that a new standard requires the use of an existing standard. Unlike patent citations, standard references are thus a direct indicator of use of the technology. We only take into account *new* references; i.e. we identify and disregard references from new versions of existing standards, if prior versions of the same standard already included the reference.

Table 3 presents the results of OLS regressions estimating the effects of the rate at which the active standards of a cohort are referenced by new standards on firm survival and growth. We find a statistically significant and positive correlation between new references and the rate at which existing firms of the same cohort create new establishments. The effects on other dimensions of change in firms are not statistically significant.

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard references (new)	0.0156	-0.0331	0.0172	-0.0136	0.0195	0.0247**
	0.0138	0.0265	0.0120	0.0195	0.0339	0.0084
agecat_0	0.0000	-0.1273***	-0.0697***	0.8648***	0.9921***	1.9383***
	.	0.0070	0.0032	0.0051	0.0089	0.0022
agecat_1	0.2072***	0.1819***	0.1740***	0.1559***	-0.0259**	-0.0357***
	0.0095	0.0072	0.0033	0.0053	0.0092	0.0023
agecat_2	0.1483***	0.1556***	0.1144***	0.0913***	-0.0643***	-0.0054*
	0.0095	0.0073	0.0033	0.0054	0.0094	0.0023
agecat_3	0.1234***	0.1177***	0.0887***	0.0687***	-0.0490***	-0.0049*
	0.0095	0.0074	0.0033	0.0054	0.0094	0.0023
agecat_4	0.1065***	0.0990***	0.0720***	0.0575***	-0.0415***	-0.0050*
	0.0095	0.0074	0.0033	0.0054	0.0094	0.0023
agecat_5	0.0954***	0.0846***	0.0600***	0.0458***	-0.0389***	-0.0055*
	0.0095	0.0071	0.0032	0.0053	0.0091	0.0023
agecat_6to10	0.0739***	0.0570***	0.0386***	0.0288***	-0.0282**	-0.0047*
	0.0095	0.0067	0.0030	0.0049	0.0086	0.0021
agecat_11to15	0.0549***	0.0289***	0.0182***	0.0137**	-0.0152*	-0.0031
	0.0095	0.0060	0.0027	0.0045	0.0077	0.0019
agecat_16to20	0.0468***	0.0117*	0.0081**	0.0034	-0.0083	-0.0024
	0.0095	0.0059	0.0027	0.0044	0.0076	0.0019
agecat_21to25	0.0418***	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0096	.	.	.	.	.
Constant	0.0511***	0.1263***	0.0873***	0.1360***	0.0097	0.0461***
	0.0130	0.0145	0.0066	0.0107	0.0185	0.0046
Observations	274	311	311	311	311	311

Table 3: Econometric results: effects of rate of *new* references to technology standards of the same vintage

Once again, we examine the temporal relationship between standard references and the rate at which firms create new establishments. Figure 6 displays the coefficients of the lags and leads of the rate at which the same standard cohort is cited. In a stark contrast to the temporal relationship identified between standard withdrawal and firm deaths, the creation of new establishments is positively correlated with future, but not with past rates of standard references.

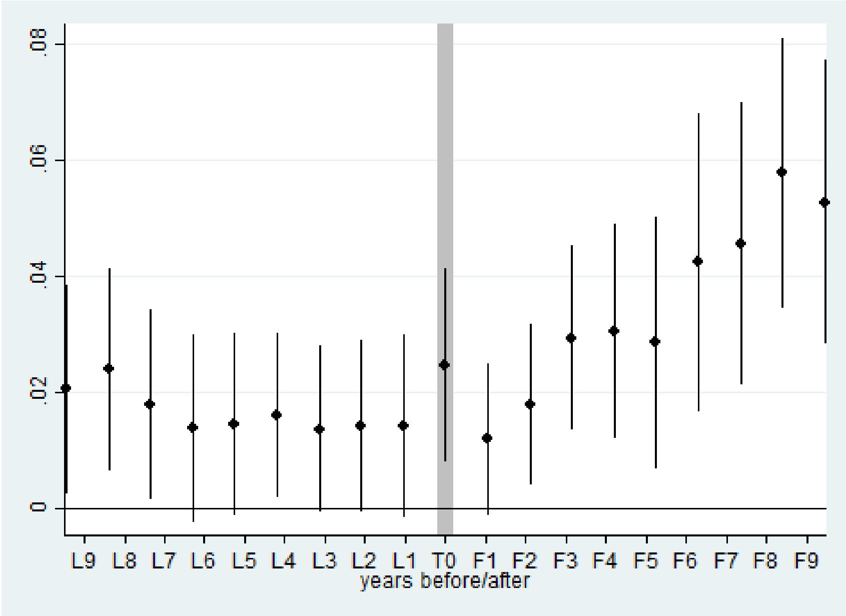


Figure 6: Coefficients and 95% CI effect of reference rate on establishment entry rate (same cohort, lags and leads in years)

In Figure 7, we examine the contemporaneous relationship between new establishments created by the firms of a cohort and the rate at which new standards reference standards that were released in the years before or after the firms in this cohort were created. In line with the results in Figure 5, we find that establishment creation by a cohort of firms is correlated with the rate of references to standards that are slightly younger than the firms. Nevertheless, the effect is most pronounced for standards released in the same year in which the firms were created.

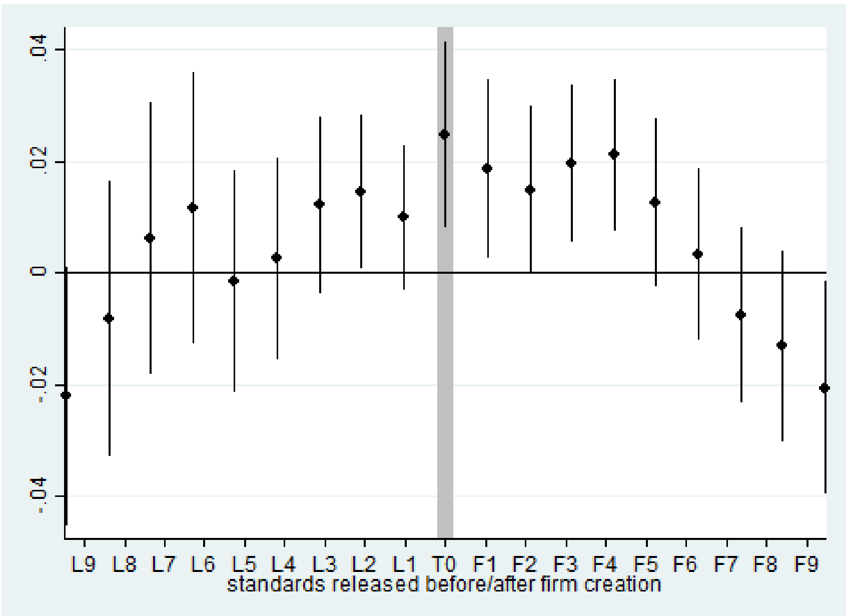


Figure 7: Coefficients and 95% CI effect of reference rate to standard cohorts released before/after firm creation (in years) on establishment entry rate

5.5 Small vs. large firms

In addition to age categories, the Census Bureau's BDS data-set provides the rates of firm survival and growth by firm size, industry and state. In this section, we analyze how firms of different sizes are affected by technological change as measured by changes in technology standards. We classify firms into small (1 to 9 employees), medium (10 to 99 employees) and large (100 or more employees) according to their number of employees at the beginning of the year. For exposition purposes, we present the coefficients and confidence intervals of the variable of interest only; the full regression results are presented in the Appendix in Tables 6 to 11.

In Figure 8, we present the effects of the standard withdrawal rate on the survival and growth of small, medium size and large firms. The results are qualitatively roughly consistent across the different samples. For firms of all sizes, standard withdrawal rates are statistically significantly and positively correlated with firm deaths (not significant for medium-size firms), establishment exits, and job destruction, and statistically significantly and negatively correlated with establishment entries. Nevertheless, the effects are much more significant for large firms than for small or medium-size firms. This finding can be interpreted as an indication that large firms are more significantly adversely affected by discontinuous technological change than smaller firms; presumably because they have more physical and organizational capital associated with a specific technology and face higher costs of technological replacement.

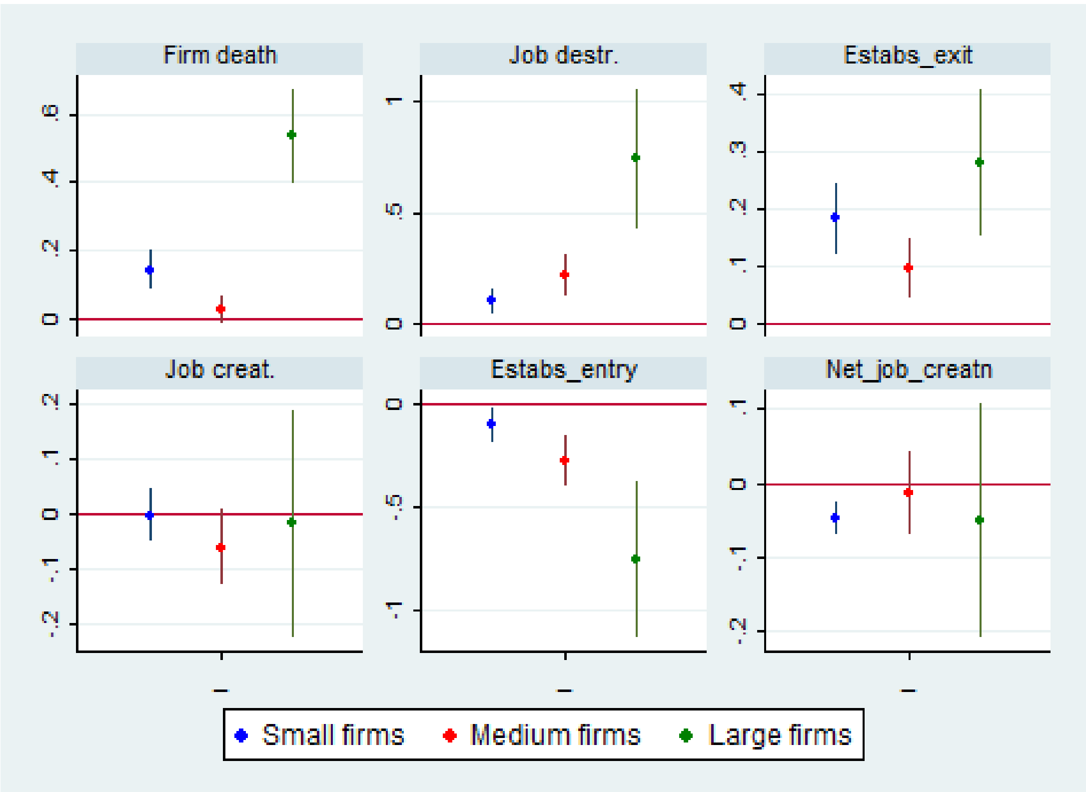


Figure 8: Effects of standard withdrawal rate on small, medium size and large firms

In Figure 9, we present the results of an analysis of the effects of the rate of standard references on small, medium size and large firms. Even though large firms again seem to be more significantly affected than other firms, none of the results is statistically significant for any of the sub-samples of firms considered in isolation.

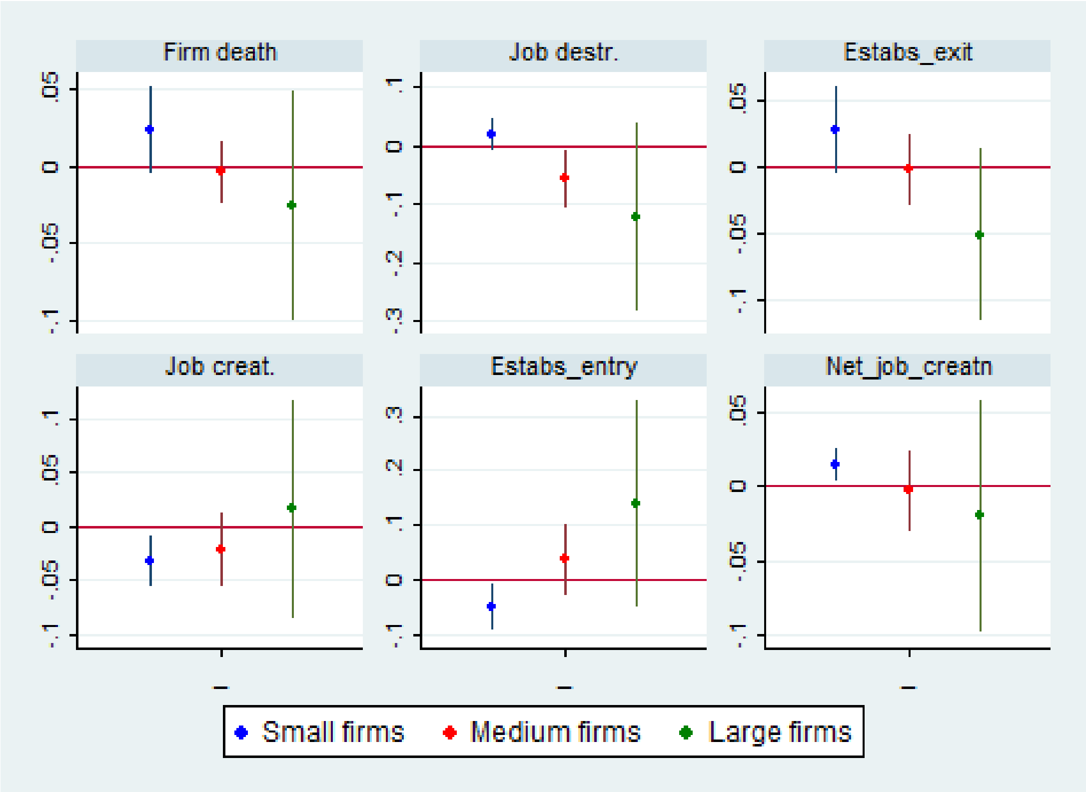


Figure 9: Effects of reference rate to standard cohorts on small, medium size and large firms

5.6 Extensions

The Searle Center Database provides rich bibliographical information about standards. In this section, we differentiate the effects of standard withdrawal and reference rates by national/international origin and technological field.

In Figure 10, we present the effects of standard withdrawal rates on firm survival and growth, differentiating between standard documents issued by SSOs classified as national (US based) and international. The results are qualitatively and quantitatively similar and consistent.

In Figure 11, we present the effects of standard reference rates, once again differentiating between standard documents issued by national (US based) and international SSOs. The results are more heterogeneous. In particular, the correlation between references and establishment entry is only significant for US standards. US standards also exhibit a positive and statistically significant correlation between reference rates and firm deaths, establishment exits and job destruction. These somewhat puzzling results warrant further investigation.

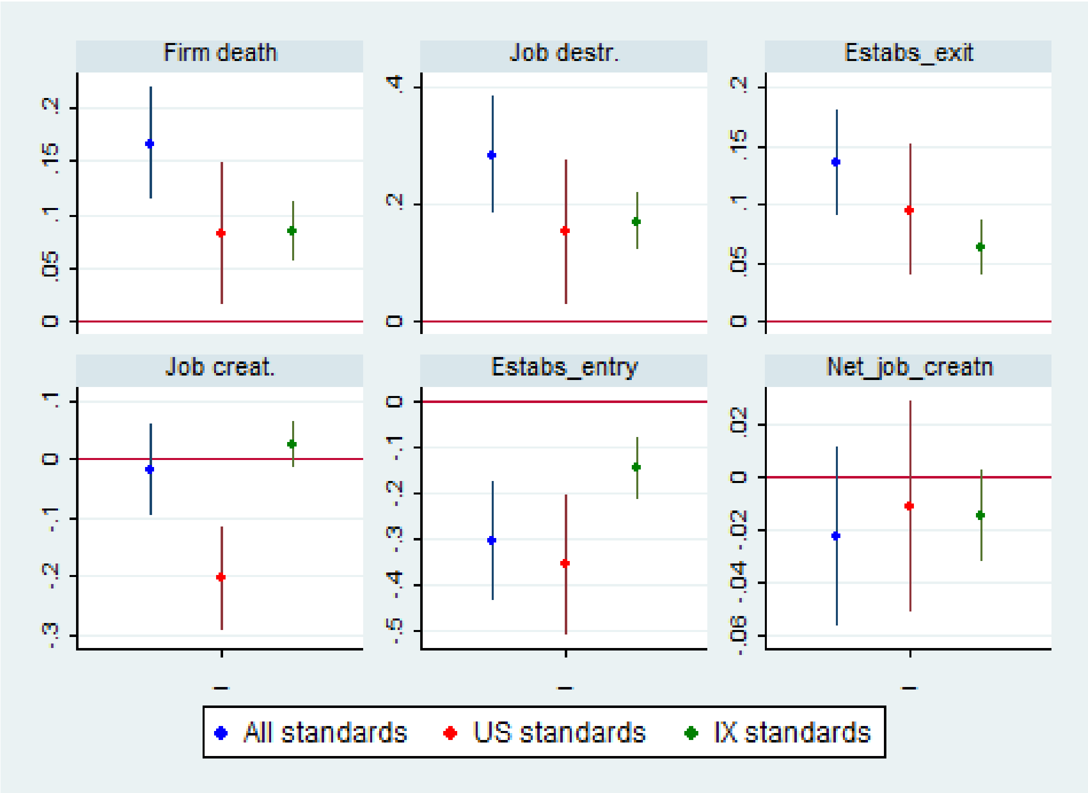


Figure 10: Effects of the withdrawal rate of all, US, and international standards

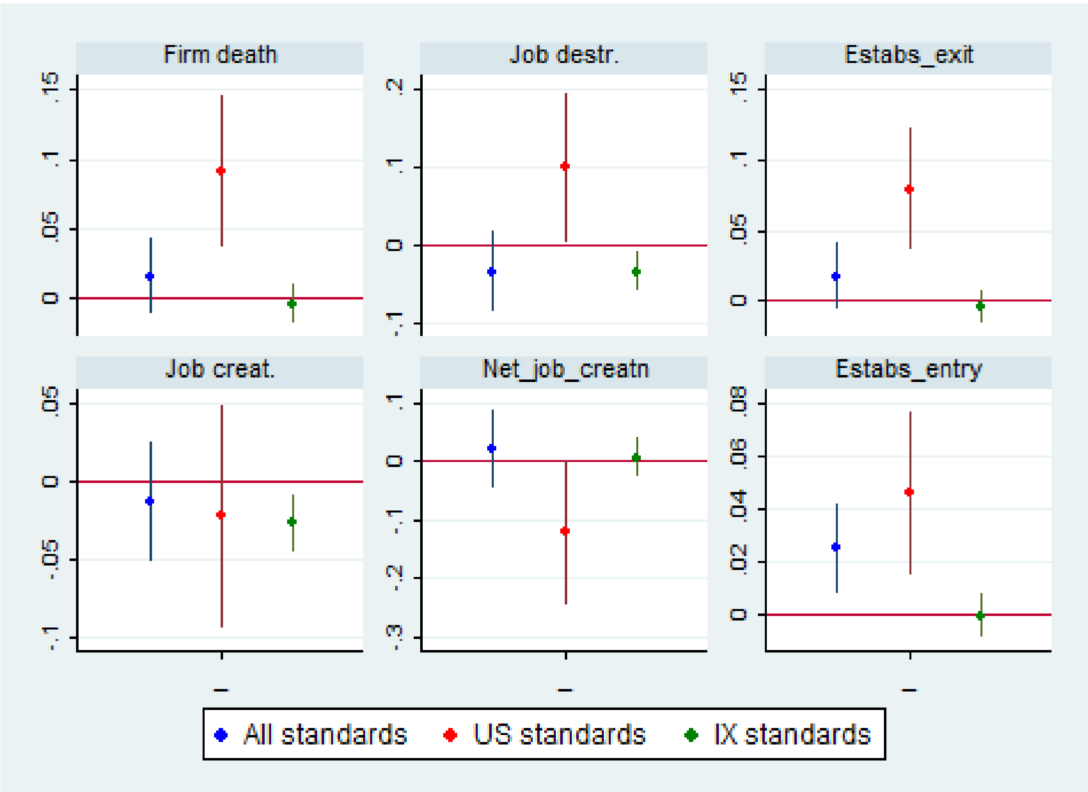


Figure 11: Effects of the rate of references to all, US, and international standards

In Figures 12 and 13, we present the results of the same analyses, differentiating between US and international standards, but focusing exclusively on ICT standards.

The number of ICT standards, especially US ICT standards, is much smaller than the total population of standards. The effects are thus measured with very large confidence intervals, and in the case of the US ICT standards, no statistically significant effects are visible. Among international ICT standards, we can confirm the positive and statistically significant relationship between standard withdrawal and firm deaths, establishment exits and job destruction.

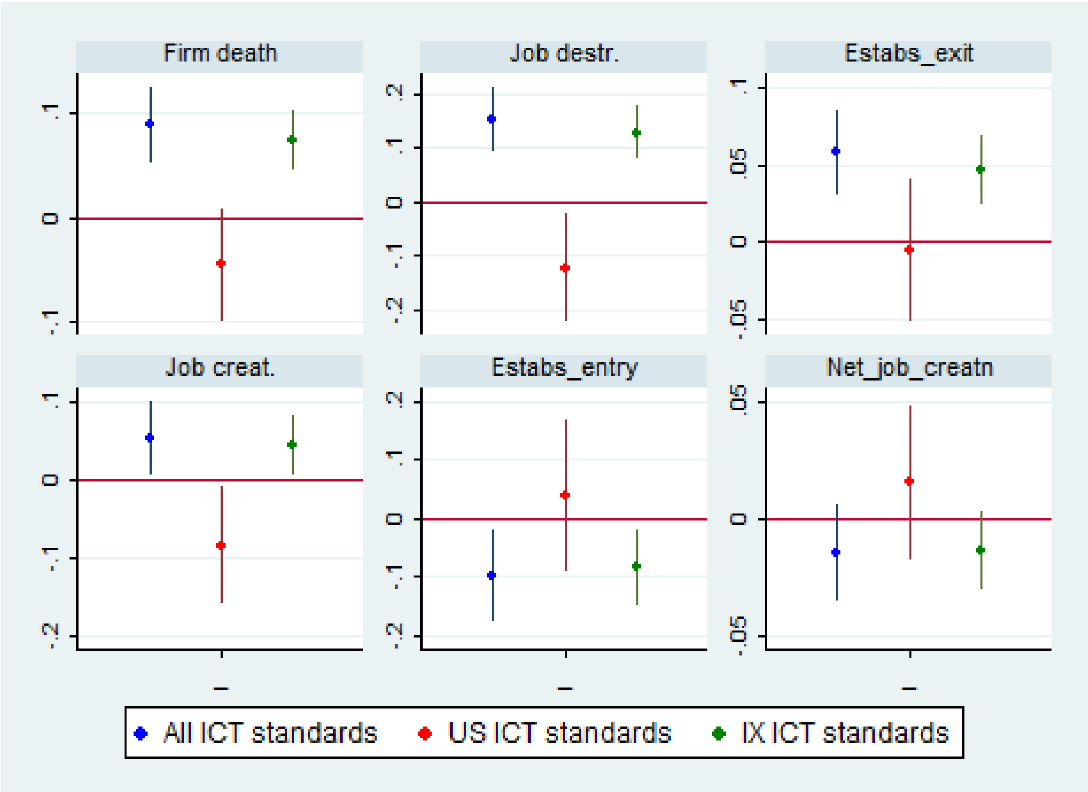


Figure 12: Effects of the withdrawal rate of all, US, and international ICT standards

Figure 13: Effects of the rate of references to all, US, and international ICT standards

5.7 Robustness

5.7.1 Fractional Response Generalized Linear Models

The firm death rate, establishment exit rate, and job destruction rate are *proportions* bound between 0 and 1. An OLS estimation of proportions may result in impossible predicted values below 0 or above 1. This may affect the estimation of the coefficient, because OLS understates the influence of observations with values close to 0 or 1. Several estimators can be used to analyze proportion outcomes (e.g. OLS with a logit transformation of the dependent variable). We use the stata routine **fracglm** (Williams, 2016), which estimates Fractional Response Generalized Linear Models (Papke and Wooldridge, 1996), and specify robust standard errors to account for heteroskedasticity.

We report average marginal effects in Table 4. The results are qualitatively and quantitatively very similar to the OLS results. The estimates for the effect of standard withdrawal on firm death are slightly lower, with a point estimate of 0.1151% increase in the firm death rate for a 1% increase in the standard withdrawal rate. All other estimates are within the confidence intervals of the OLS estimates. We therefore conclude that the simplifying use of OLS throughout the analysis was justified.

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) firmdeath b/se	(5) jobdestruct b/se	(6) estabs_exit b/se
Standard withdrawal rate	0.1151***	0.2783***	0.1281***			
	0.0261	0.0494	0.0217			
Standard references				0.0046	-0.0224	0.0156
				0.0085	0.0181	0.0085
agecat_0	-0.9894***	-2.2854***	-1.5889***	-0.9821***	-2.2645***	-1.5836***
	0.0183	0.0257	0.0180	0.0184	0.0256	0.0180
agecat_1	0.1568***	0.1311***	0.1434***	0.1684***	0.1641***	0.1542***
	0.0040	0.0061	0.0040	0.0031	0.0067	0.0038
agecat_2	0.1217***	0.1224***	0.1113***	0.1289***	0.1455***	0.1173***
	0.0025	0.0045	0.0032	0.0024	0.0054	0.0033
agecat_3	0.1038***	0.0989***	0.0949***	0.1087***	0.1165***	0.0983***
	0.0021	0.0037	0.0030	0.0024	0.0051	0.0034
agecat_4	0.0886***	0.0849***	0.0819***	0.0930***	0.1013***	0.0847***
	0.0020	0.0037	0.0030	0.0024	0.0053	0.0034
agecat_5	0.0748***	0.0685***	0.0687***	0.0812***	0.0891***	0.0739***
	0.0022	0.0043	0.0031	0.0023	0.0049	0.0033
agecat_6to10	0.0511***	0.0491***	0.0493***	0.0552***	0.0635***	0.0523***
	0.0020	0.0037	0.0030	0.0021	0.0045	0.0032
agecat_11to15	0.0243***	0.0274***	0.0260***	0.0264***	0.0345***	0.0273***
	0.0019	0.0035	0.0029	0.0019	0.0038	0.0030
agecat_16to20	0.0097***	0.0125***	0.0119***	0.0104***	0.0147***	0.0124***
	0.0019	0.0035	0.0030	0.0019	0.0038	0.0031
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Observations	274	311	311	274	311	311

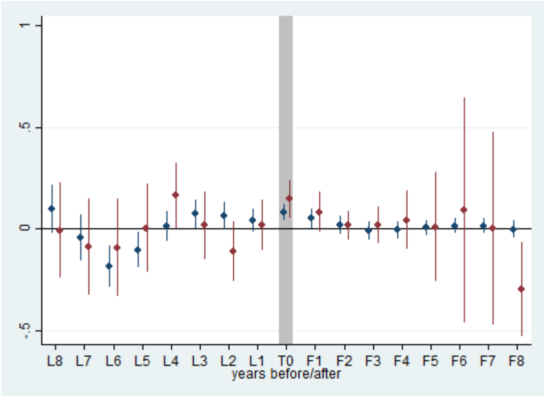
Table 4: Econometric results: marginal effects from Fractional Response Generalized Linear Models

5.7.2 Alternative dataset with firm age in years

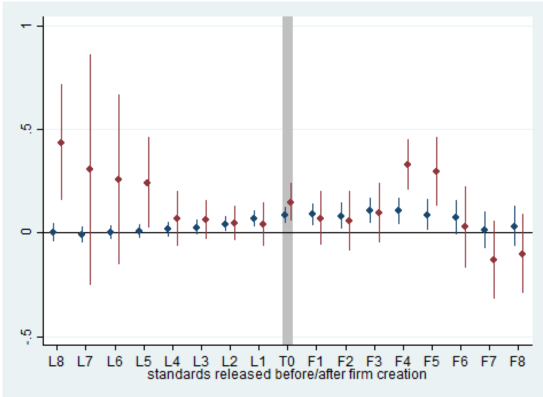
Throughout the analysis, we used the age categories provided by the US Census Bureau. For firms older than 5 years, we thus can only observe the approximate age (and hence cohort) by intervals of five years. The Bureau of Labor Statistics (BLS) provides data on the survival rates of firms created since 1994 by age indicated in years.[13] While this data-set offers age in years up to 20 years, it only includes data on survival rates of firms, and none of the other components of business dynamics. Furthermore, it only spans more recent years, and younger firms, than the data that we obtained from the US Census Bureau. For the main analysis, we thus preferred using the data from the US Census Bureau.

As a robustness check, we estimate the effect of standard withdrawal on firm death rates with firm age in years, using the BLS data. For the purpose of comparison, we also re-estimate the effect of standard withdrawal on firm death rates with firm age in age categories. We can thus determine whether differences in the estimated effects result from

[13]https://www.bls.gov/bdm/entrepreneurship/bdm_chart3.htm



(a) Same cohort, lags and leads in years



(b) Same year, younger/older cohorts of standards

Figure 14: Coefficients and 95% CI effect of standard withdrawal rate on firm death rate, with firm age in years (blue) or age categories(red)

the different levels of aggregation of firm age or the different samples. The results in Table 5 indicate that the estimated effect of standards withdrawal is slightly lower when firm age is expressed in years (with an 0.0827% increase in the firm death rate for a 1% increase in the standard withdrawal rate), but this also results to some extent from the restriction to younger firms and more recent years. The point estimate from the regression with firm age in years is within the confidence interval of the estimation with age categories and the same restricted sample.

	(1)	(2)
	yearly	agecat
	b/se	b/se
USIX_withdr_rate_m	0.0827***	0.1473**
	0.0194	0.0461
Observations	231	109

Table 5: Econometric results: effects of standard withdrawal on firm death rate, yearly and by age category

We also compare the results of the analyses of the dynamics between firm death rates and standard withdrawal rates. The results are very similar for lower lags and leads, and standards released shortly before or after the creation of the firm cohort. The estimations using firm age in years are significantly more precise than estimations using age categories for greater lags or leads or greater divergence between the date of firm creation and standard release. In contrast to our earlier findings, only contemporaneous effects are significant (i.e. we don't confirm that standard withdrawal rates lead firm death rates), but this seems to be attributable to the smaller sample and not the different definition of firm age. We confirm that firm death rates are significantly associated with the withdrawal rates of standards released within five years after firm creation (this effect is not statistically significant for all years for the estimations using the smaller sample and age categories, but it is significant in the more precise estimations using firm age in years). Overall, our results are thus qualitatively robust to using firm age in years instead of the Census Bureau's age categories.

6 Conclusion

In this paper, we explore a new source of empirical information on technological change to study the dynamics of firm growth, decline and exit. We find robust evidence for creative destruction, i.e. a positive relationship between technological change manifested in standard withdrawals and the destruction of firms, establishments and jobs. It is important to underline that these destructive effects are concentrated in the cohorts of firms most directly associated with the replaced technology; and may be offset by creative effects in other firms. We also find evidence for such creative effects of technological change on incumbent firms. In particular, we find evidence that firm cohorts associated with standards that are referenced by new standards create new establishments at a higher rate.

This analysis is purely empirical; and is not intended to yield welfare or policy implications about the desirability of technological change. In particular, with our empirical framework, we cannot measure one of the likely main effects of new technology: jobs created in new firms. Nevertheless, by providing new empirical insights based on an original and novel data-source, we can contribute to a better and thicker understanding of the economic implications of technological change.

The contribution of our paper to the literature is twofold. First, we provide empirical evidence corroborating the hypothesized relationship between firm dynamics and technological change. In particular, our results are broadly consistent with the literature on vintage capital. In this literature, firms' marginal cost of technology adoption increases with age, so that firms are characterized by a technological dependency on the technology vintage that was state of the art when they were created. Our results confirm that the growth and survival prospects of firms depend to some extent on the degree to which the technology standards that were released in the same year in which the firms were created continue to be used. This is perhaps the most direct observation of such a vintage-specific technological change which is currently available, and significantly corroborates an important stream of macro-economic theory with far-reaching implications for the analysis of business cycles and economic growth.

Second, we validate technology standards as a measure of technological change, which promises to be useful for countless economic research questions. Even though technology standards are ubiquitous, and standardization is almost as old as civilization itself, economists have been slow to recognize the enormous potential of empirical data derived from technology standard documents. This paper highlights some of the main advantages of technology standards as a measure of technological change. In particular, the rich bibliographic information on version histories and standard references opens up the black-box of the *direction* of technological change.

References

D. Acemoglu, U. Akcigit, and W. Kerr. Innovation network. Working Paper 6173, CESifo Center for Economic Studies and Ifo Institute, November 2016.

R. Agarwal and M. Gort. The evolution of markets and entry, exit and survival of firms. *Review of Economics and Statistics*, 78(3):489–498, August 1996.

P. Aghion and P. Howitt. A model of growth through creative destruction. *Econometrica*, 60:323–351, 1992.

P. Aghion, U. Akcigit, and P. Howitt. What do we learn from schumpeterian growth theory? In *Handbook of Economic Growth*, volume 2, pages 515–563. Elsevier, 2014.

U. Akcigit and W. Kerr. Growth through heterogeneous innovations. March 2015.

M. Alexopoulos. Read all about it!! what happens following a technology shock? *American Economic Review*, 101(4):1144–1179, June 2011.

B. Arthur. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, 99:116–131, March 1989.

M. Asplund and V. Nocke. Firm turnover in imperfectly competitive markets. *Review of Economic Studies*, 73(2):295–327, 2006.

J. Baron and J. Schmidt. Technological standardization, endogenous productivity and transitory dynamics. mimeo, 2016.

J. Baron and D. Spulber. Technology standards and standards organizations: An introduction to the searle center database. mimeo, 2016.

J. Baron, T. Pohlmann, and K. Blind. Essential patents and standard dynamics. *Research Policy*, 45(9):1762–1773, 2016.

E. Bartelsman and M. Doms. Understanding productivity: Lessons from longitudinal microdata. *Journal of Economic Literature*, 38(3):569–594, 2000.

S. Besen and J. Farrell. Choosing how to compete: Strategies and tactics in standardization. *Journal of Economic Perspectives*, 8(2):117–131, Spring 1994.

B. Biddle, A. White, and S. Woods. How many standards in a laptop? (and other empirical questions). Technical report, September 2010. Available at SSRN: https://ssrn.com/abstract=1619440 or http://dx.doi.org/10.2139/ssrn.1619440.

A. Bonatti and H. Rantakari. The politics of compromise. *American Economic Review*, 106(2):229–259, February 2016.

R. J. Caballero and M. L. Hammour. The cleansing effect of recessions. *American Economic Review*, 84(5):1350–1368, December 1994.

R. J. Caballero and M. L. Hammour. On the timing and efficiency of creative destruction. *Quarterly Journal of Economics*, 111(3):805–852, 1996.

J. Campbell. Entry, exit, embodied technology, and business cycles. *Review of Economic Dynamics*, 1(2):371–408, April 1998.

J. Clougherty and M. Grajek. International standards and international trade: Empirical evidence from iso 9000 diffusion. *International Journal of Industrial Organization*, 36: 70–82, September 2014.

M. Doms, T. Dunne, and M. Roberts. The role of technology use in the survival and growth of manufacturing plants. *International Journal of Industrial Organization*, 13 (4):523–542, 1995.

T. Dunne. Plant age and technology use in us. manufacturing industries. *RAND Journal of Economics*, 25(3):488–499, Autumn 1994.

D. S. Evans. The relationship between firm growth, size and age: Estimates for 100 manufacturing industries. *Journal of Industrial Economics*, 35(4):567–581, June 1987.

L. Foster, J. Haltiwanger, and C. Krizan. Market selection, reallocation, and restructuring in the u.s. retail trade sector in the 1990s. *Review of Economics and Statistics*, 88(4): 748–758, 2006.

J. Galí. Technology, employment, and the business cycle: Do technology shocks explain aggregate fluctuations? *American Economic Review*, 89(1):249–271, March 1999.

D. Garcia-Macia, C.-T. Hsieh, and P. Klenow. How destructive is innovation? mimeo, 2016.

L. Goerke and M. Holler. Voting on standardisation. *Public Choice*, 83:337–351, 1995.

S. Graham, C. Grimm, T. Islam, A. Marco, and J. Miranda. Business dynamics of innovating firms: Linking u.s. patents with administrative data on workers and firms. Working Paper Seires No. 2015-30, GeorgiaTech Scheller College of Business, 2015.

Z. Griliches. Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, 28(4):1661–1707, December 1990.

G. Grossman and E. Helpman. Quality ladders in the theory of growth. *Review of Economic Studies*, 58(1):43–61, 1991.

J. Haltiwanger. Job creation and firm dynamics in the united states. In J. Lerner and S. Stern, editors, *Innovation Policy and the Economy, Volume 12*, pages 17–38. University of Chicago Press, Chicago, 2012.

J. Haltiwanger, R. Jarmin, and J. Miranda. Who creates jobs? small versus large versus young. *The Review of Economics and Statistics*, 95(2):347–361, May 2013.

R. Jarmin and J. Miranda. The longitudinal business database. Working paper, Center for Economic Studies, July 2002.

J. B. Jensen, R. McGuckin, and K. Stiroh. The impact of vintage and survival on productivity: Evidence from cohorts of u.s. manufacturing plants. *Review of Economics and Statistics*, 83(2):323–332, 2001.

B. Jovanovic. Selection and the evolution of industry. *Econometrica*, 50(3):649–670, May 1982.

B. Jovanovic and S. Lach. Entry, exit, and diffusion with learning by doing. *American Economic Review*, 79(4):690–699, September 1989.

B. Jovanovic and Y. Nyarko. Learning by doing and the choice of technology. *Econometrica*, 64(6):1299–1310, November 1996.

S. Klepper. Entry, exit, growth, and innovation over the product life cycle. *American Economic Review*, 86(3):562–583, June 1996.

S. Klepper and K. Simons. The making of an oligopoly: Firm survival and technological change in the evolution of the u.s. tire industry. *Journal of Political Economy*, 108(4): 728–760, 2000.

T. Klette and S. Kortum. Innovating firms and aggregate innovation. *Journal of Political Economy*, 112(5):986–1018, 2004.

A. Kurmann and E. Sims. Revisions in utilization-adjusted tfp and robust identification of news shocks. NBER Working Paper 23142, National Bureau of Economic Research, February 2017.

R. Lucas and B. Moll. Knowledge growth and the allocation of time. *Journal of Political Economy*, 122(1):1–51, 2014.

G. Moscarini and F. Postel-Vinay. The contribution of large and small employers to job creation in times of high and low unemployment. *American Economic Review*, 102(6): 2509–2539, 2012.

G. S. Olley and A. Pakes. The dynamics and productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263–1297, November 1996.

L. E. Papke and J. M. Wooldridge. Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. *Journal of Applied Econometrics*, 11(6):619–632, December 1996.

C. Pentheroudakis and J. Baron. Licensing terms of standard essential patents: A comprehensive analysis of cases. Jrc science for policy report eur 28302, Joint Research Centre of the European Commission, 2017. available from http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104068/jrc104068

P. M. Romer. Endogenous technological change. *Journal of Political Economy*, 98(5): 71–102, 1990.

M. Rysman and T. Simcoe. Patents and the performance of voluntary standard-setting organizations. *Management Science*, 54(11):1920–1934, November 2008.

R. M. Samaniego. Entry, exit, and investment-specific technical change. *American Economic Review*, 100(1):164–192, 2010.

J. A. Schumpeter. *The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle*. Harvard University Press, Cambridge, MA, 1934.

T. Simcoe. Standard setting committees: Consensus governance for shared technology platforms. *American Economic Review*, 102(1):305–336, February 2012.

R. Solow. Technical change and the aggregate production function. *Review of Economics and Statistics*, 39:312–320, 1957.

D. Spulber. Innovation economics: The interplay among technology standards, competitive conduct, and economic performance. *Journal of Competition Law and Economics*, 9(4): 777–825, December 2013.

D. Spulber. Standard setting organizations and standard essential patents: Voting power versus market power. mimeo, April 2016.

J. Sutton. Gibrat's legacy. *Journal of Economic Literature*, 35(1):40–59, 1997.

P. Swann, P. Temple, and M. Shurmer. Standards and trade performance: The uk experience. *The Economic Journal*, 106(438):1297–1313, 2005.

R. Williams. Analyzing proportions: Fractional response and zero one inflated beta models. Technical report, April 2016. available at: https://www3.nd.edu/ rwilliam/stats3/FractionalResponseModels.pdf.

Appendix

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard withdrawal	0.1449***	0.1029***	0.1833***	-0.0039	-0.1068*	-0.0480***
	0.0275	0.0285	0.0317	0.0241	0.0412	0.0107
agecat_0	-0.0714***	-0.1583***	-0.0998***	0.8462***	1.0045***	0.9662***
	0.0033	0.0034	0.0038	0.0029	0.0049	0.0013
agecat_1	0.1514***	0.1145***	0.1931***	0.2011***	0.0866***	-0.0191***
	0.0040	0.0042	0.0046	0.0035	0.0060	0.0016
agecat_2	0.0961***	0.1029***	0.1166***	0.1150***	0.0121*	0.0160***
	0.0034	0.0035	0.0039	0.0030	0.0051	0.0013
agecat_3	0.0750***	0.0840***	0.0901***	0.0874***	0.0034	0.0157***
	0.0031	0.0032	0.0036	0.0027	0.0047	0.0012
agecat_4	0.0589***	0.0696***	0.0718***	0.0703***	0.0007	0.0148***
	0.0031	0.0032	0.0036	0.0027	0.0046	0.0012
agecat_5	0.0451***	0.0567***	0.0552***	0.0606***	0.0039	0.0152***
	0.0033	0.0034	0.0038	0.0029	0.0049	0.0013
agecat_6to10	0.0263***	0.0371***	0.0341***	0.0415***	0.0044	0.0127***
	0.0031	0.0032	0.0035	0.0027	0.0046	0.0012
agecat_11to15	0.0098**	0.0175***	0.0146***	0.0202***	0.0027	0.0085***
	0.0030	0.0031	0.0034	0.0026	0.0045	0.0012
agecat_16to20	0.0033	0.0065*	0.0053	0.0086**	0.0022	0.0038**
	0.0030	0.0032	0.0035	0.0027	0.0046	0.0012
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	0.0975***	0.1635***	0.1371***	0.1674***	0.0039	0.0246***
	0.0073	0.0076	0.0085	0.0064	0.0110	0.0029
Observations	311	311	311	311	311	311

Table 6: Econometric results: effects of standard withdrawal rate on small firms

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard withdrawal	0.0254	0.2211***	0.0961***	-0.0609	-0.2820***	-0.0133
	0.0203	0.0484	0.0268	0.0342	0.0643	0.0280
agecat_0	-0.0269***	-0.1527***	-0.0541***	0.8890***	1.0417***	0.9717***
	0.0024	0.0058	0.0032	0.0041	0.0077	0.0033
agecat_1	0.1218***	0.1558***	0.1116***	0.1342***	-0.0215*	0.0073
	0.0030	0.0071	0.0039	0.0050	0.0094	0.0041
agecat_2	0.0856***	0.1251***	0.0747***	0.0870***	-0.0381***	0.0134***
	0.0025	0.0059	0.0033	0.0042	0.0079	0.0034
agecat_3	0.0643***	0.0932***	0.0541***	0.0662***	-0.0270***	0.0099**
	0.0023	0.0055	0.0030	0.0039	0.0073	0.0032
agecat_4	0.0500***	0.0740***	0.0421***	0.0557***	-0.0182*	0.0077*
	0.0023	0.0054	0.0030	0.0038	0.0072	0.0031
agecat_5	0.0402***	0.0550***	0.0306***	0.0446***	-0.0104	0.0039
	0.0024	0.0058	0.0032	0.0041	0.0077	0.0034
agecat_6to10	0.0229***	0.0347***	0.0181***	0.0292***	-0.0055	0.0029
	0.0023	0.0054	0.0030	0.0038	0.0072	0.0031
agecat_11to15	0.0086***	0.0149**	0.0057*	0.0128***	-0.0021	0.0016
	0.0022	0.0052	0.0029	0.0037	0.0070	0.0030
agecat_16to20	0.0029	0.0056	0.0015	0.0033	-0.0023	-0.0005
	0.0023	0.0054	0.0030	0.0038	0.0071	0.0031
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	0.0228***	0.1340***	0.0490***	0.1125***	-0.0215	0.0286***
	0.0054	0.0129	0.0072	0.0091	0.0172	0.0075
Observations	311	311	311	311	311	311

Table 7: Econometric results: effects of standard withdrawal rate on medium size firms

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard withdrawal	0.5341***	0.7405***	0.2808***	-0.0185	-0.7590***	-0.0501
	0.0690	0.1577	0.0645	0.1036	0.1903	0.0806
agecat_0	-0.0379***	-0.1733***	-0.0746***	0.8547***	1.0281***	0.9067***
	0.0082	0.0188	0.0077	0.0124	0.0227	0.0096
agecat_1	0.1027***	0.1715***	0.0468***	0.1046***	-0.0668*	0.0615***
	0.0101	0.0230	0.0094	0.0151	0.0278	0.0118
agecat_2	0.0658***	0.1539***	0.0258**	0.0710***	-0.0829***	0.0475***
	0.0085	0.0194	0.0079	0.0127	0.0234	0.0099
agecat_3	0.0415***	0.0942***	0.0137	0.0580***	-0.0362	0.0320***
	0.0078	0.0179	0.0073	0.0118	0.0216	0.0092
agecat_4	0.0281***	0.0763***	0.0076	0.0584***	-0.0180	0.0308***
	0.0077	0.0177	0.0072	0.0116	0.0213	0.0090
agecat_5	0.0096	0.0516**	-0.0008	0.0443***	-0.0073	0.0239*
	0.0083	0.0189	0.0077	0.0124	0.0228	0.0097
agecat_6to10	0.0053	0.0255	-0.0006	0.0279*	0.0025	0.0158
	0.0077	0.0176	0.0072	0.0116	0.0212	0.0090
agecat_11to15	0.0003	0.0140	-0.0006	0.0162	0.0022	0.0075
	0.0075	0.0171	0.0070	0.0112	0.0206	0.0087
agecat_16to20	0.0003	0.0066	0.0018	0.0041	-0.0025	0.0028
	0.0076	0.0175	0.0071	0.0115	0.0211	0.0089
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	0.0067	0.2150***	0.0826***	0.1343***	-0.0807	0.0853***
	0.0184	0.0421	0.0172	0.0277	0.0509	0.0216
Observations	311	311	311	311	311	311

Table 8: Econometric results: effects of standard withdrawal rate on large firms

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard references (new)	0.0239	0.0186	0.0266	-0.0314**	-0.0500*	0.0151**
	0.0142	0.0145	0.0166	0.0118	0.0205	0.0054
agecat_0	-0.0663***	-0.1550***	-0.0928***	0.8511***	1.0061***	0.9607***
	0.0037	0.0038	0.0044	0.0031	0.0054	0.0014
agecat_1	0.1622***	0.1219***	0.2075***	0.2063***	0.0844***	-0.0268***
	0.0039	0.0039	0.0045	0.0032	0.0056	0.0015
agecat_2	0.1016***	0.1065***	0.1242***	0.1205***	0.0140*	0.0100***
	0.0039	0.0040	0.0046	0.0033	0.0057	0.0015
agecat_3	0.0775***	0.0855***	0.0941***	0.0930***	0.0075	0.0105***
	0.0040	0.0040	0.0046	0.0033	0.0057	0.0015
agecat_4	0.0608***	0.0707***	0.0749***	0.0759***	0.0052	0.0099***
	0.0040	0.0040	0.0046	0.0033	0.0057	0.0015
agecat_5	0.0498***	0.0598***	0.0618***	0.0657***	0.0059	0.0097***
	0.0038	0.0039	0.0045	0.0032	0.0055	0.0015
agecat_6to10	0.0288***	0.0386***	0.0378***	0.0458***	0.0072	0.0086***
	0.0036	0.0037	0.0042	0.0030	0.0052	0.0014
agecat_11to15	0.0109***	0.0182***	0.0162***	0.0226***	0.0044	0.0064***
	0.0032	0.0033	0.0038	0.0027	0.0047	0.0012
agecat_16to20	0.0038	0.0068*	0.0060	0.0093***	0.0025	0.0032**
	0.0032	0.0032	0.0037	0.0026	0.0046	0.0012
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	0.0914***	0.1595***	0.1288***	0.1624***	0.0030	0.0305***
	0.0078	0.0079	0.0091	0.0064	0.0112	0.0030
Observations	311	311	311	311	311	311

Table 9: Econometric results: effects of rate of new standard references on small firms

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard references (new)	-0.0036	-0.0570*	-0.0032	-0.0211	0.0359	-0.0032
	0.0101	0.0247	0.0136	0.0170	0.0330	0.0139
agecat_0	-0.0248***	-0.1297***	-0.0476***	0.8887***	1.0184***	0.9714***
	0.0027	0.0065	0.0036	0.0045	0.0087	0.0037
agecat_1	0.1251***	0.1889***	0.1222***	0.1316***	-0.0573***	0.0064
	0.0027	0.0067	0.0037	0.0046	0.0090	0.0038
agecat_2	0.0880***	0.1507***	0.0818***	0.0867***	-0.0639***	0.0131***
	0.0028	0.0068	0.0038	0.0047	0.0091	0.0038
agecat_3	0.0662***	0.1145***	0.0593***	0.0672***	-0.0473***	0.0099*
	0.0028	0.0069	0.0038	0.0047	0.0092	0.0039
agecat_4	0.0518***	0.0942***	0.0469***	0.0570***	-0.0373***	0.0077*
	0.0028	0.0069	0.0038	0.0047	0.0092	0.0039
agecat_5	0.0424***	0.0780***	0.0370***	0.0445***	-0.0335***	0.0036
	0.0027	0.0066	0.0037	0.0046	0.0089	0.0037
agecat_6to10	0.0244***	0.0517***	0.0225***	0.0297***	-0.0221**	0.0028
	0.0026	0.0062	0.0034	0.0043	0.0083	0.0035
agecat_11to15	0.0094***	0.0237***	0.0079*	0.0132***	-0.0105	0.0016
	0.0023	0.0056	0.0031	0.0039	0.0075	0.0032
agecat_16to20	0.0032	0.0083	0.0022	0.0033	-0.0050	-0.0005
	0.0023	0.0055	0.0030	0.0038	0.0074	0.0031
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	0.0205***	0.1091***	0.0418***	0.1132***	0.0041	0.0290***
	0.0055	0.0135	0.0074	0.0093	0.0180	0.0076
Observations	311	311	311	311	311	311

Table 10: Econometric results: effects of rate of new standard references on medium size firms

	(1) firmdeath b/se	(2) jobdestruct b/se	(3) estabs_exit b/se	(4) job_creat b/se	(5) netjobcreat b/se	(6) estabs_entry b/se
Standard references (new)	-0.0261	-0.1222	-0.0516	0.0162	0.1384	-0.0203
	0.0379	0.0811	0.0330	0.0514	0.0968	0.0400
agecat_0	-0.0006	-0.1076***	-0.0488***	0.8509***	0.9586***	0.9069***
	0.0100	0.0213	0.0087	0.0135	0.0255	0.0105
agecat_1	0.1629***	0.2703***	0.0852***	0.0999***	-0.1704***	0.0598***
	0.0103	0.0220	0.0090	0.0140	0.0263	0.0109
agecat_2	0.1069***	0.2268***	0.0544***	0.0668***	-0.1600***	0.0478***
	0.0105	0.0224	0.0091	0.0142	0.0267	0.0110
agecat_3	0.0723***	0.1529***	0.0370***	0.0541***	-0.0988***	0.0334**
	0.0105	0.0226	0.0092	0.0143	0.0269	0.0111
agecat_4	0.0564***	0.1315***	0.0295**	0.0546***	-0.0770**	0.0324**
	0.0105	0.0225	0.0092	0.0143	0.0269	0.0111
agecat_5	0.0464***	0.1172***	0.0249**	0.0404**	-0.0768**	0.0243*
	0.0102	0.0218	0.0089	0.0138	0.0260	0.0108
agecat_6to10	0.0307**	0.0729***	0.0182*	0.0249	-0.0480	0.0166
	0.0096	0.0205	0.0083	0.0130	0.0245	0.0101
agecat_11to15	0.0131	0.0382*	0.0090	0.0146	-0.0236	0.0080
	0.0086	0.0185	0.0075	0.0117	0.0221	0.0091
agecat_16to20	0.0044	0.0141	0.0047	0.0037	-0.0104	0.0029
	0.0085	0.0181	0.0074	0.0115	0.0217	0.0090
agecat_21to25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	.	.	.	.	.	.
Constant	-0.0347	0.1432**	0.0545**	0.1382***	-0.0049	0.0853***
	0.0207	0.0443	0.0180	0.0281	0.0529	0.0219
Observations	311	311	311	311	311	311

Table 11: Econometric results: effects of rate of new standard references on large firms