NBER WORKING PAPER SERIES

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Working Paper 32844
http://www.nber.org/papers/w32844

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2024, Revised April 2026

We thank Vladimir Belykh and Ayush Sinha for excellent research assistance, and Orren Ravid for help with the initial data. We thank the participants to the NBER Digital Economics workshop 2023 (in particular our discussant Catherine Tucker), the Mallen Conference, the Chicago Entrepreneurship Festival, the 2024 FMA, EFA 2024 and EFMA and SFA 2025 as well as seminar participants at Harvard Business School, Yale SOM, NYU Stern, Yeshiva University Syms School of Business, Drexel, Tel Aviv University, the Hebrew University, Ben Gurion University, Lund University, University of Stockholm, University of Gothenburg, Haifa University, and at KU Leuven for comments. All errors are our own. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 32844
August 2024, Revised April 2026
JEL No. D22, L2, M19

ABSTRACT

This paper studies the impact of career concerns on technological change by analyzing the adoption of digital cinematography in the US motion picture industry. This setting allows us to collect rich data on the adoption of this new technology at the project level (i.e., movie) as well as on the career of the main decision maker (i.e., director). We find that early career directors played a leading role in the adoption of digital technology and that this effect appears to be explained by career concerns, rather than alternative motives we consider and analyze. Technological savviness also plays a role.

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1 Introduction

In this study, we empirically investigate how career concerns affect technology adoption dynamics, with a specific focus on the transition to digital cinematography in the motion picture industry during the early 2000s—a pivotal period when digital recording began to gain prominence among professional filmmakers. Our findings reveal that early-career directors were at the forefront of adopting digital technology. Notably, first-time directors were over three times as likely to adopt digital filmmaking compared to very experienced directors. Movie directors' careers are very risky. Most of the directors in our sample drop out after one project. Our analysis suggests that the drive to stand out and the willingness to embrace riskier technologies as well as the costs and benefits of embracing new technologies in a very uncertain career path—may explain why less established directors were keener to adopt innovative technologies. These results contrast with the documented behavior of early career professionals in the financial industry.

The adoption of new technologies is often slow, even when these new technologies can bring important benefits to the adopter (Geroski, 2000). Several theories have been offered to explain this slow diffusion process. For instance, some papers show that the speed and depth of technology adoption depend on organizational and incentive constraints (Atkin et al, 2017). Other work focuses on learning and informational frictions (e.g., Munshi, 2004, Conley and Udry, 2010, Gupta et., 2023), coordination (e.g., Caoui, 2022, Crouzet et al., 2023, Feigenbaum and Gross, 2022), or financial development (e.g., Comin and Nanda, 2019; Bircan and De Haas, 2019).

In general, an adoption decision is made by individuals, who can be executives in large companies or entrepreneurs in smaller entities. Therefore, individual incentives and career concerns may influence technology adoption in firms.[1] Research has shown that career concerns affect day-to-day decision making (e.g., Jensen and Murphy, 1990, Gibbons and Murphy,1992, Chevalier and Ellison, 1999b; Goldfarb and Xiao, 2011). For instance, several papers focusing on the financial industry find that early-career professionals tend to prefer safer options and are more likely to follow some form of "herd behavior" (e.g., Chevalier and Ellison, 1999a; Hong, Kubik, and Solomon, 2000; Lamont, 2002). However, the type of industry and the nature of the tasks studied (i.e., core on-the-job activities) imply that this research may not be as informative about the role of career concerns for a transformative decision such as technology adoption.

In fact, technology adoption differs from traditional investment decisions or other more routine tasks in several ways. First, the adoption of a new technology naturally involves the abandonment of an older technology where experienced managers may have extensive knowledge. Second, new technology is generally riskier,[2] which can either come from the novelty of the technology or from the uncertainty about its commercial applications. Third, a new technology is generally not introduced at its full potential, which may imply that early adopters can benefit from joining at the early stages of development. However, others may prefer to wait until the technology is fully developed.

In this context, we argue that it is ex-ante unclear how career considerations may affect the decision to adopt a new technology.[3] Experienced managers already have some pre-existing knowledge about the old technology and may not want to put in the effort to learn a new one. Newcomers, on the other hand, have no experience with either technology, and they need to put effort into learning

[1] Some of the prominent papers in the career concerns literature include Holmstrom and Ricart-i-Costa, 1986; Gibbons and Murphy, 1992, Prendergast and Stole, 1996; and Holmstrom, 1999.
[2] While we would argue that this is a crucial feature of most new technologies, we will also show empirical evidence that is consistent with this hypothesis in the specific setting studied here (Section 3).
[3] In addition to the qualitative discussion in Section 3, the paper proposes a simple stylized model in Appendix B.

both technologies. However, typical career-concerns models (e.g., Holmstrom, 1999) as well as our data, suggest that experienced managers are also more secure in their career prospects, irrespective of the outcome of their next project. As a result, they are more likely to internalize any long-term benefits of adopting new technology early and thus may be early adopters. The high level of risk that characterizes new technologies may complicate the problem further. Inexperienced managers may either avoid high risk strategies (as in Hong et al. 2000 or Chevalier and Ellison, 1999a) or if the career progression is sufficiently uncertain, as is the case for our film directors, may take greater risks.[4] In other words, theory provides ambiguous predictions regarding the role of career concerns in technology adoption decisions.[5].

The literature does acknowledge the role of managers in the adoption of new technology (e.g., Acemoglu et al., 2022; Agrawal, Gans, and Goldfarb, 2019). However, a major obstacle to empirically studying the effect of career concerns on technology adoption is the lack of project-level data that allows the researcher to match information about the agent who makes the decision (i.e., the manager) with the actual adoption behavior. For instance, within firms it is often difficult to determine who exactly is making decisions regarding adoption. This paper overcomes these limitations by examining the adoption of digital movie making during the early 2000s. Using data from the Internet Movie Database (IMDb), we observe the decision making at the film-director level. For each film in our data, we manually assess whether the camera and other equipment used in production were film or digital. Thus, we know the name of the manager making the decision

[4] As we discuss in Section 3, the level of competition is important to understand the direction of the effect of risk on adoption. In careers characterized by low level of competition (e.g., most managers will keep their job in the future), managers are more concerned with minimizing downside risks, and therefore they will prefer avoiding a new technology. Instead, in highly competitive careers (e.g., a manager keeps her job only if the performance is exceptional), managers tend to be risk-seeker.

[5] In a very different context (the match between innovating firms and CEOs of different vintages) Acemoglu et al. (2022) formalize and analyze some of the ideas discussed here.

to adopt a new technology, we know the timing of their decision, as well as the entire trajectory of his or her career. This makes it possible to assess whether career considerations are important for this decision.[6] Another important feature of this setting is that a director's career is risky and starts at a relatively late age, hence career concerns are of paramount importance (e.g., John et al, 2017, Han and Ravid, 2025).

The context of our experiment is the adoption of digital cinematography in the early years of this century. While available, digital shooting was rarely used to produce movies in the 1990s. There were two main constraints on the diffusion of digital filmmaking. First, the quality of the early digital output was still low relative to the quality of the traditional film. Second, the economic benefits from switching to digital were limited as long as studios had to print and distribute a movie on film. While the quality of digital cameras had been constantly improving over time, the second issue was not resolved until after 2007, when movie theaters and production companies reached a financial agreement which allowed the widespread installation of digital projection. Consistent with this narrative, the adoption of digital cinematography follows a typical S-curve (Rogers, 1962): digital was very rare until the early 2000s, started to grow at a much faster rate at the beginning of the millennium, as quality improved, before taking off post-2007. Our core focus will be on the period before this latter shift (early-adoption period) when (a) we see the first significant wave of adoption of digital technology in features films; (b) there were weaker economic benefits of adopting digital technology implying that directors had greater autonomy to decide which technology they should use for shooting.

[6] Digital technology in film can be viewed as part of the digital revolution, or a general-purpose technology (GPT) in the sense of Agrawal et al. (2022). However, here we focus on a specific industry and specific processes to study career concerns and technology adoption.

We show that experience is a strong predictor of the likelihood of using digital technology: more experienced directors – for instance, as measured by the number of past movies – are less likely to use digital. A one standard-deviation increase in experience translates to a roughly 20% decline in the average probability of using digital during this period. Furthermore, we find that the largest drop in the probability of adoption is when we compare first-time directors to directors with some experience. These results are robust to a variety of different modeling choices and are not driven by differences in genres or ratings as well as other confounding factors.

One way to further confirm our findings is to examine how these results change in response to structural changes in the market. The financial incentives to use digital technology increased significantly after 2006, as movie theaters started to adopt digital projection, thereby reducing the distribution cost of movies shot digitally. We find that our results are largely driven by directors' behavior until 2006. As we argue later, this pattern broadly aligns with a career concerns framework, rather than alternative explanations, such as bargaining power of directors versus financiers (studios).[7]

We can also more directly rule out some of the leading alternative mechanisms that may explain our results. First, we address the bargaining power issue. Second, we find that our main result does not reflect an inherent preference for "digital" content among early-career directors. Our data collection allows us to identify movies that were shot on film but were later transferred at least in part into digital prints during the post-production phase.[8] We can replicate our findings when we

[7] For instance, this finding appears at odds with explanation of the differential response that are tied to the higher quality/facility of the digital technology or pressure by the production companies. We further discuss these hypotheses in Section 4.

[8] This step could be taken to incorporate special effects or other changes that are easier to conduct in digital format. Notice that this "digital intermediate" technology was already used at the end of the 1990s and it did not present the same risks as shooting directly in digital, since the original material was always available in film.

use this sub-sample as the control group. Third, we show that the results are not driven by the early exposure to digital technologies, or by the age of the director but rather by the career stage.

We also examine the role of technical expertise as an explanation for our results. We measure general technical knowledge, not necessarily specific knowledge about digital cinematography, by examining past technical roles individuals had in other films. We do find that technical expertise favors adoption. However, the technical expertise mechanism operates independently from the career concerns of the director identified earlier.

Our paper contributes to several areas of economics. Broadly, we are part of the large technology adoption literature studying how organizational factors affect the process of technological progress (Azoulay and Lerner, 2013). Specifically, our paper highlights the importance of managerial incentives in understanding the patterns of technology adoption within an industry. Our findings also add to our understanding of frictions that prevent the adoption of valuable technologies (e.g., Atkin et al, 2017; Bircan and De Haas, 2019; Comin and Nanda, 2019; Conley and Udry, 2010; Crouzet et al., 2023; Crouzet et al, 2026; Feigenbaum and Gross, 2022; Gupta et., 2023; Munshi, 2004, Acemoglu et al. 2022). A general conclusion from our work is that the type of career progression and the mix of early career and more experienced employees may critically affect the extent and timing of technology adoption in industries, in particular during the early-adoption period in the typical technology diffusion model (Rogers, 1962). This factor may explain why different companies – even when they face a similar economic and institutional environment – may differ in the process of technological upgrading. We also document the role of experience and expertise in the technical aspects of production in adopting new technology.[9]

[9] Our analysis complements work in innovation focusing on understand how demographic factors affect the production of new technologies, as in Acemoglu et al. (2022), Derrien et al. (2023), and Barker and Mueller (2002). Our work

This paper also contributes to the literature in finance that studies the effects of career concerns on managers' behavior. Theoretical contributions include for example, Holmstrom (1999) MacDonald (1988), Prendergast and Stole (1996) – this latter paper reaches similar conclusions as we do from a somewhat different perspective. Focusing largely on the investment industry, several papers show that younger managers tend to avoid bold decision making, and instead try to align their behavior with the most common strategy in the market (e.g., Chevalier and Ellison, 1999a; Hong, Kubik, and Solomon, 2000; Lamont, 2002).[10] As discussed, our paper finds a different result: among movie directors, less experienced directors are more willing to take the riskier strategy of adopting a new technology. While there can be various mechanisms that explain this difference, we believe that career concerns are the most likely explanation. As mentioned earlier, in our setting risk taking makes sense for less experienced managers. The level of competition among movie directors is high, and therefore success is defined only by an exceptionally positive result. In contrast, in the financial industry, where people are much more likely to keep their jobs than lose it, inexperienced managers who still need to build up their reputation may prefer to play it safe (e.g., herding or using an established technology).[11] This interpretation is consistent with evidence from Bowen et al. (2017), who examine another high-pressure industry, namely,

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differs from these papers because it focuses specifically on technology diffusion rather than innovation, and examines the role of experience, rather than age. By the same token, our paper also differs from Crouzet et al., (2026), which studies how businesses' technology adoption may internalize consumers' preferences for technology. Furthermore, our work focuses on the importance of manager's experience in making decisions, while Crouzet et al., (2026) is interested on how consumers' heterogeneity can be internalized by otherwise homogenous entrepreneurs.

[10] An exception to this is Li, Low and Makhija (2017), who study CEO behavior. Interestingly, the authors explain the difference in results because the previous literature in finance has focused mostly on highly specialized labor market (e.g., mutual fund managers), where the need to herd could be stronger. Our paper focuses on a very specialized labor market, but still find results that are inconsistent with the herding literature (see Section 5). Ferrer and Okulicz (2024) provides another empirical test of career concerns outside the financial industry, focusing on the lawyer market and studying the implications of career concerns in markets with opponents.

[11] This discussion is also related to the branch of literature focused on herding behavior (Hirshleifer and Teoh, 2003), and in particular how this type of behavior relates to seniority (Ottaviani and Sorensen, 2001).

academia and find that early career faculty are more likely to adopt new empirical methodologies.[12] Our paper proposes a simple framework that can be used to guide this discussion across different technologies and industries.

Our paper also relates to the literature focused on the technological development in the movie industry (e.g., Hennig-Thurau et al., 2021, Weinberg et al., 2021). For instance, Caoui (2022) studies the adoption of digital projection for movie theaters in France. He finds that the presence of network effects between movie theaters adopting digital projection and production companies selling digital movies can generate significant excess inertia. Similarly, Yang et al. (2021) study the effect of the diffusion of digital exhibition in South Korea on the choice of films available to consumers. Nagaraj and Ranganathan (2022) show how digital recording of music for Indian movies affected the gender diversity of singers in this market: among other things, their analysis confirms our interpretation of the digital transition as a fundamental shock to the production function of creative content. In other words, their discussion highlights how shifting to digital does not simply change the medium of recording, but this shift also changes the overall process of producing new content, potentially allowing for more experimentation (Kerr et al., 2014) and flexibility. Similarly, in our context digital cinematography is fundamentally different from film technology.[13]

[12] While our results share some similarities with Bowen et al. (2017), the underlying mechanisms and empirical setting are fundamentally different. The diffusion of new empirical methodologies in finance involves relatively limited downside risk: researchers can adopt identification techniques at a low cost and with little exposure to project-level failure. In contrast, adopting digital cinematography entails a substantial real risk for directors, as discussed. Consistent with this difference, Bowen et al. (2017) emphasize learning—through doctoral training or peer networks—as the central driver of adoption. Although our analysis also highlights the role of learning costs in shaping diffusion, it shows that career concerns (in particular via risk-taking) play a central role in explaining digital technology adoption in our setting.

[13] Our paper also contributes to the large literature using the motion picture industry as a laboratory to study the labor market and industrial dynamics. Just to provide a few examples, Han and Ravid (2025) discuss the market for film directors; Chisholm and Norman (2006) study the optimal exit choice in a multi-product market; Gil (2015) examines

The rest of the paper is organized as follows. In Section 2, we present our empirical setting as well as the data. In Section 3, we present a conceptual framework and develop our hypotheses. In Section 4, we present the empirical analysis and several robustness checks. In Section 5, we discuss our results, with a focus on external validity. In Section 6, we conclude.

2 Background and Data

This section surveys the transformation to digital production in the movie industry, which is the focus of this paper. We use a combination of information from our movie data set, anecdotal evidence from the news media, background discussions with industry executives and others, and some original quotes from a survey of movie directors that we conducted to gather some qualitative information on the way professional directors think about digital versus film technology.[14] In the second part of this section, we describe in detail the data used in the empirical part of the paper.

2.1 Digital Movies

Movies have been shot on film since the beginning of the motion picture entertainment era. Digital technology started as an expensive toy in the 1980s although the potential for cost savings and simplification of the filmmaking process was clear from the beginning. The first full-length movie shot using a digital camera, the Sony High-Definition video system, was Julia and Julia (1987) with Kathleen Turner and Sting. However, the movie had to be converted back to film to be shown in theaters.

the effect on antitrust on pricing using the movie theater industry as a setting; Gil and Lampe (2014) study the adoption to color in the movie industry; Raut et al. (2008) studies contract complexity in the movie industry.

[14] To run the survey, we collected the full list of directors who are members of the Directors Guild of America and provide their email address in the association portal. The main objective of the short survey was to improve our qualitative understanding of how professional directors see digital versus film shooting. We provide several quotes from the survey results throughout the study. Two hundred and twenty feature film directors answered the survey (as well as several hundreds of directors who had never directed a feature). The vast majority of respondents used digital technology at some point.

In fact, one of the key constraints to the mass adoption of digital filming was economic. Digital technology was cheaper during the recording and editing phase (but, as discussed later, the production process was different, and the quality of the finished product was initially relatively low). However, as long as movie theaters were equipped with traditional projection technologies, the digital output had to be transferred to film and shipped to theaters for exhibition. Thus, the net economic benefit of filming a movie digitally was (at best) limited.

In 1999, George Lucas and others introduced the first digital projectors. These projectors cost around $250,000 and theater owners in a declining market claimed they could not afford them without support from producers. In 2002 major movie studios formed a committee to develop standards ("All things considered," NPR, Mark Uryck, May 13, 2002). However, as of October 2003 there were only 80 digital cinemas in the US and 200 around the world (Eric Taub, New York Times, October 13, 2003). In November 2004, The National Association of Theater Owners publicly agreed to digital projection, stating that costs of the new systems should be split between exhibitors and studios (UPI.com, November 22, 2004).

Despite these coordination efforts, the downstream impact was still limited. [15] By 2007, some theater chains had started converting to digital on a larger scale, but only 2200 screens out of 38,000 in the US were digital. The financial breakthrough around that time was that studios agreed to pay a fee for every digital copy they shipped (Virtual Print Fee or VPF) to help in financing the initial purchase of digital projectors (NPR, "All Things Considered," Laura Seidel, March 21, 2007). VPFs were introduced gradually around the country and the world. In 2008 the number of

[15] Economists had suggested that studios and theaters share the costs and benefits of digital projection long before agreements were signed. See for example a NY Times piece by one of the authors: DIGITAL CINEMA; Sharing the Cost - The New York Times

digital screens jumped to 5515. [16] By 2012, the cost of digital projectors had declined to $75,000 and financial agreements such as VPF allowed theaters to engage in digital projection. The number of digital screens jumped again to 33000 out of less than 40,000 in total. By 2015, 4900 of 5700 theaters in the US used digital projection, under various financing agreements. In 2019, only 602 out of over 40,000 screens were not digital. Therefore, the economic outlook for digital cinematography improved dramatically after 2007, when the ability to distribute digitally lowered costs relative to film which now had to be converted to digital for exhibition. A similar adoption pattern was also present outside the US (Caoui, 2022).

Another important aspect of digital shooting is the impact of the medium on quality. Slumdog Millionaire (2008) became the very first movie with digital cinematography to win an Academy Award for Best Cinematography as well as the best film award. In recent decades, digital technology has become progressively cheaper and digital effects have become more accessible. However, even in recent years, as the quality of digital filming has improved and more than 90% of movies are shot on digital, there are still directors who argue that film has some quality advantages. For instance, Quentin Tarantino famously suggested that he “might retire” if forced to shoot digital, saying “I can’t stand this digital stuff” and that digital was “TV in public”.[17] The well-known director Steve McQueen, a supporter of film shooting, told the New Republic in 2014: “all this technology, it’s changing every five minutes because someone’s making some money out of it.” Other directors supporting film include the recent academy award winner Christopher Nolan. Nolan’s Tenet, one of the very few films to be released in the pandemic year of 2020, was

[16] U.S. & Canada: no. of cinema screens by format 2021 | Statista
[17] https://www.digitalspy.com/movies/a441960/quentin-tarantino-i-cant-stand-digital-filmmaking-its-tv-in-public/

shot on film as was his recent academy award winning film Oppenheimer (mostly on large format film cameras).

At the other end of the spectrum, some well-known, experienced directors were early adopters. Oscar winner Steven Soderbergh was one of the first to shoot with a “red camera.” Similarly, Danny Boyle, the director of Slumdog Millionaire was another early adopter, and Martin Scorsese, a leader in the directing field, shot the Wolf of Wall Street in a digital format in 2012.

This discussion highlights how the choice between digital and film mostly reflects a director’s preference and her expectation about the type of project to be undertaken. Furthermore, we should emphasize that shooting on digital does not mean just using different cameras for principal photography. The entire production process changes. An experienced top movie executive with stints in several major studios told us that directors who shot on digital stock tended to spend more time on set since retakes were costless and that meant that studios had to watch the number of days in principal photography. Responses by directors in our survey reinforce this sentiment. One director said that digital was “faster both for shooting and editing” and another stated digital allowed them to “do repeated takes without cutting.” In a similar setting, Nagaraj and Ranganathan (2022) describe how the advent of digital audio recording completely changed the production process for movies’ music in India.

This short history shows that the process of technology adoption in the creative industries can be far from linear, and that throughout the process leaders in the industry have had very different views of the new technology. Our data allows us to track individual project managers and characterize their actions vis a vis this evolving technology.

2.2 Data on Directors and Technologies

The key pieces of information necessary to study technology adoption in the movie industry are the type of equipment chosen by directors as well as movie and director characteristics. We collect most of the necessary data from the Internet Movie Database (IMDb). IMDb is an online database owned by Amazon. It maintains unique webpages for each film as well as for individuals associated with the production of movies, such as film directors. The film webpages contain information on the technical production process, the content of the film such as genre and rating, and various measures of the film's success such as reviews and box office revenue. Individual webpages contain detailed information on the individual's participation in filmed entertainment in a variety of roles. We focus on directorial roles for theatrical films, defined below.

We start by obtaining from IMDb the list of all films released in the United States from 1975 to 2018 with gross box office revenue of at least $10,000 (2018 inflation-adjusted USD).[18] This filter allows us to focus only on movies that targeted a release in U.S. movie theaters, therefore excluding TV content, smaller foreign productions that did not make it to the U.S. market, and importantly non-professional productions. This choice is partly motivated by the distinct career incentives faced by directors of theatrically released motion pictures, which differ from those of TV directors or creators involved in non-professional productions.

From the IMDb page we collect film-level data about how the film was created, its content, and various measures of success such as user ratings and box office revenue. The most important information for our purposes relates to the film's production process found in the "Technical

[18] The following link displays films released in the United States in 2000 contained in IMDb: https://www.imdb.com/search/title/?title_type=feature&year=2000,2000&sort=boxoffice_gross_us,desc&ref_=adv_nxt

Specifications" section on the film web page. This section allows us to categorize the equipment used to shoot the film as either film or digital.

We focus on the "Camera" and "Cinematographic Process" fields of the technical specifications section. We create a comprehensive dictionary of all unique cameras and cinematographic processes used in the filming of movies in our sample. We then manually attempt to verify whether the camera or cinematographic process uses film or digital through online internet searches as well as discussions with professionals. To illustrate the categorization process, consider the 2013 film Dallas Buyers Club. The technical specifications page shows that the camera used to shoot the film was an Arri Alexa, a popular digital camera. Furthermore, the cinematographic process "ProRes 4:4:4 (1080/24P)" is associated with digital filming. Given this information, Dallas Buyers Club is categorized as a digitally shot film. In some instances, a film's technical specifications suggest both digital and film cameras were used in production. We consider these films digital given that the director chose to adopt digital film technology for at least part of the filming process. The filming technology can be categorized for most films, although for any given year a handful are uncategorized either because the camera cannot be assigned as either film or digital or the camera is missing from the technical specifications page.

While we collect films in IMDb from 1975 to 2018, we begin film categorization in 1995 since there was practically no digital filming prior to that year. For films that can be categorized Figure 1 shows the proportion of film and digitally shot movies from 1995 to 2018. The story depicted by this figure matches the anecdotal evidence discussed in the previous section. In the early 2000s, the share of digital films was extremely limited. However, adoption started to increase during the early 2000s, and the share of digital films increased steadily, reaching approximately 21% in 2008. As discussed earlier, after that year the adoption of digital photography increased even more rapidly as digital projectors were being installed in theaters, shifting the economic incentives of the studios in favor of digital. Indeed, we see that by 2018, over 94% of movies are digital. We note that this behavior is broadly consistent with a typical S-curve discussed in the technology diffusion literature (e.g., Rogers, 1962). In this context, the period between the early 2000s and 2007 could be referred to as the "early-adoption period," when the technology was gaining market share despite still being used by a minority of projects in the market.

We also want to note that our categorization process depicted in Figure 1 is consistent with the work of Stephen Follow, a data journalist who specializes in the film industry. In a blog post, Follow categorizes the camera type for the top 100 grossing films in the United States from 2000-2015.[19] The trend in adoption of digital cameras he documents is nearly identical to our categorization, therefore confirming the quality of our approach.

In addition to film characteristics collected from the film's webpage, we obtain information about the directors of the films. For each person involved in the entertainment industry, IMDb creates a web page which provides detailed career information. For directors, that page includes the history of films the individual directed, as well as a list of other roles they may have had in film production and television (i.e., credits). This career information is useful to control for other potential mechanisms affecting the decision to adopt digital technology. For example, if an individual had previous experience in technical roles (e.g., as a cinematographer, or a visual effect director) she may find it easier to adopt digital technology when she becomes a director. The resulting dataset

[19] For more information on Stephen Follow's categorization of camera types see: https://stephenfollows.com/film-vs-digital/

is at the film-director level containing all films with U.S. box office revenue of at least $10,000 from 1975 to 2018.[20]

3 Directors and Career Concerns in the Movie Industry

In this section, we discuss how career concerns can influence technology adoption. First, we describe some key features of new technologies that are important for adoption incentives and then we develop explicit hypotheses about how such career concerns can affect technology adoption given the specific characteristics of the industry. An illustrative model is presented in appendix B.

3.1 Movie Directors' Role and Career Progression

The adoption of digital filming can provide new insights into how a manager's career concerns can affect the incentive to adopt a new technology. Film directors are responsible for both the creative and the business aspects of the film they direct. They provide the vision but also must bring the project to a conclusion on time and within budget. In our context, they can be considered as project managers who need to decide which technology to adopt in order to maximize their career prospects in an uncertain labor environment.

People who are not familiar with the movie industry may think that producers are the "project managers". However, while the term "producer" has multiple meanings in the industry it tends to designate financiers and overseers (like shareholders and boards) rather than project managers. The closest to the latter designation are directors.[21] The exchange between the director of the movie

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[20] This amount is somewhat arbitrary, but it is approximately the take for one screen in a small theater for one week (one week is also the cutoff for academy award consideration). This methodology biases the sample somewhat against very low-quality films (high budget, but total failures) so that we include only bad films that at least had some audience. Typically, 300-400 movies that fulfill our criteria are released every year (see Han and Ravid, 2025).

[21] As is the case in any corporate setting, there is some bargaining in every financial decision. Han and Ravid (2025), discuss the term (or credit in the movie for) producer in movies, which means many things in the business. The most important credit is that of "Producer" and it is generally accorded to the person(s) who initiate a project, sell it to a studio, and/or develops and shepherd it through the system until it is released or provide or facilitate the financing for

Sharper (shot on film in 2023) Benjamin Caron and interviewer Kerry Nolan is instructive for our purposes in illustrating that directors have autonomy over the choice of filming technology. Ms. Nolan suggests that the cinematographer chose to shoot on film and Mr. Caron corrects her: "That was a decision that I made". Then this first-time feature film maker (but long-time TV director) says: "If you want a film to look like film, I think you shoot it on film, and I don't know any other process that can do what film does."[22]

Importantly for us, directors' careers are risky and start at a late age, hence career concerns are of paramount importance for them. Han and Ravid (2025) as well as John et al. (2017) employ different data sets yet find similar results regarding the career characteristics of film directors. The average director enters the profession at age 39 and makes only one film before dropping out and returning to their previous profession. In Han and Ravid (2025), 84% of male directors who entered the profession between 1995 and 2015 and 90% of the female directors in the same cohort made only one or two films before dropping out. Given that the average budget in that sample is over $40 million in 1998 dollars, it is not surprising that a failure or a mild success are not sufficient to put directors in charge of additional projects worth tens of millions of dollars.[23] In our sample, although it was again constructed very differently and not focused on the entire career of directors, we find that 70% of the directors drop out after the first movie, and 85% after two movies.

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the project. The Executive Producer credit is usually reserved for a variety of people associated in some form at one time or another with a project. In the independent film world Executive Producer is often a credit accorded to individuals who assisted in raising financing for a film, or who are associated with a financial company or fund that finances a picture. See also the Wall Street Journal article entitled " A plague of Executive Producers" (12/2019) (https://www.wsj.com/articles/a-plague-of-executive-producers-11577648316?mod=searchresults&page=1&pos=3) In other words, the term "producer" may refer to various roles, but producers may originate the project or finance it.

[22] https://www.wnyc.org/story/director-benjamin-caron-a24-apple-tvs-sharper

[23] The situation is different for experienced directors – both papers (Han and Ravid, 2025 and John et al., 2017) show that previous success (average return or the number of movies) is a strong predictor of obtaining another assignment. Thus, more experienced directors with a good track record can afford to experiment and even fail while still being able to continue their career.

The idea that career considerations can affect the decisions of managers is not new: as previously discussed, a large theoretical literature shows that a firm's investment planning can be affected by a manager's career incentives (e.g., Holmstrom and Ricart-i-Costa, 1986; Gibbons and Murphy, 1992, Prendergast and Stole, 1996; and Holmstrom, 1999, Cisternas 2018). Empirical tests of these models usually find that younger managers tend to avoid bold decision-making and instead prefer to align their behavior with the most prevalent strategy in their relevant market (e.g., Chevalier and Ellison, 1999; Hong, Kubik, and Solomon, 2000; Lamont, 2002).

However, career concerns depend on the characteristics of the industry and on the role the individual plays in it. The way we see it, our results reinforce previous work in that we show that even if the industry context is different and even when we have a radical decision such as technology adoption, career concerns matter but they incentivize managers to act very differently.

A new technology is generally characterized by a higher level of risk. Risk in our context can come from the very nature of the technology itself or from uncertainty about market demand. For instance, in our specific context, there were concerns about whether viewers would like films shot using digital technology. This risk and the very high bar to remain in the industry incentivize managers to take very different decisions than managers in cases of established technology and a relatively low bar for continuation, for example, the financial industry.

However, previous studies also differ from our work because they focus on core business decisions (e.g., selecting stocks for a portfolio manager). The task of choosing to adopt a new technology may be different in several dimensions.[24] Unlike everyday business decisions, no current or new manager has experience with the new technology. Thus, everyone who wants to adopt the new

[24] This characterization may not be universal but it is typical of technological change and it can help the reader through our conceptual framework and our analysis.

technology including the current managers, needs to learn how to use this technology and this creates different costs and incentives for new managers vs. more established managers. The latter can stay costlessly with the old technology whereas newbies need to learn both.

Also, new technologies are usually not introduced to their full potential: adjustments and improvements are common in the early life of a new technology. As a result, if we consider the net benefit (cost) of adopting a new technology, it is likely to increase (decrease) over time relative to the old technology. This creates very different incentives for new managers who are less likely to keep their jobs compared to their more experienced peers.

The issues we mention are particularly salient in transformation into digital cinematography. Directors consider shooting on digital to be different than shooting on film (Nagaraj and Ranganathan, 2022). Not only does the result look different, but the process of creating a digital film is different. For example, it allows virtually costless repetitions of scenes and instant access to results, therefore favoring experimentation (Kerr et al., 2014). A director in our survey suggested that a major benefit of digital was “the immediacy of seeing the image on digital as opposed to having to send film to a lab and then wait to see dailies.” Another said: “It allowed me to shoot more takes and not worry as much about how much I was shooting”. On the other hand, some directors in our survey expressed concerns about digital technology. For example, one stated they were “concerned that digital would not look enough like film”.

Second, as the first wave of adoption in the early 2000s was progressing, the perception was that digital cameras still had a relatively wide margin for improvement and were generally considered of lower quality than film. For example, a director in our survey stated that “historically things shot digitally looked fake to me.” Another director said: “I started shooting digital in 1990 when it was a poor relation to film. I used it reluctantly and shot film whenever I could. By the early

2000s digital was starting to look really good (...).” On the other hand, another director commented that “[digital] was also worth learning as many believed rightly it would be the future.”

Third, movie production has always been a risky activity, like other forms of creative activity (Åstebro, 2003, Palia et al, 2008). However, recording a movie with a digital camera was perceived as a higher-risk endeavor, at least in the relevant period. Some directors in our survey mentioned risk directly. One director in our sample called digital “Cheaper, faster but risky” and another mentioned an “uncertain outcome.” A director who apparently had worked through the transition, characterized directors who decided to stay on film saying that “they took less risk” whereas the others were willing to “take that leap”.

We conclude that the transformation we describe fits well a career concerns framework. However, before we conclude this section, we would like to provide some more evidence on the relative risk of the two technologies in the period in question. Clearly, by virtue of its newness, every new technology is riskier than older technologies, However, we can also calculate returns on each film in our sample, measured as revenues divided by the production budget. Returns data indeed confirm that digital movies are characterized by relatively higher risk. In Table 1, we classify movies by their family friendliness MPA rating (i.e., G, PG, PG13, R, or Unrated) and by production choice – digital or film. We split by ratings, since prior work suggests that rating categories may differ systematically by returns and risk, and unlike genres which can overlap, they fully partition the set of films produced (Ravid, 1999, Basuroy and Ravid, 2004, Palia et al. 2008). We then compare the standard deviation of returns between these categories for movies produced between 1998-2009, as a proxy for the ex-post realized risk for each category.[25]

[25] We define returns based on the reported cost and revenues. Notice that this information is not available for all movies used in our analysis.

Digital movies show systematically higher risk compared to movies recorded on films for all rating categories. For example, PG movies recorded on films have a standard deviation of 8.91, while the SD for digital is 48.96. Given the highly skewed nature of movies' returns, we also show that this regularity does not depend on the tails of the distribution: in fact, we find the same pattern when we winsorize returns at 1%. The only partial exception to this pattern is movies rated as "PG-13:" For that category, the level of realized risk is similar between digital and film, but when we winsorize returns, again, digital movies have a significantly higher risk.[26]

The increased risk associated with digital cinematography is further substantiated through an examination of a movie's likelihood to land at the extreme tails of financial success, determined by the probability of a movie ranking in the top 10% or the bottom 10% of returns during our sample period. We see that digital movies are approximately 13% more likely than their film-based counterparts to be at either end of the return distribution. This result aligns with our earlier observations regarding the standard deviation of returns, reinforcing the conclusion that digital movies were, ex-post, riskier and perhaps more importantly, that if you wanted to land in the very upper tail of the distribution, digital was better.

In unreported results we also find that if we split the sample into first-time directors and others, the projects chosen by first-time directors in all categories, film or digital, tend to be riskier. This is consistent with the notion that less experienced directors make riskier choices, since the properties of movies by ratings are known ex-ante (see Ravid, 1999, Basuroy and Ravid, 2004).[27]

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[26] Digital movies also tend to have higher returns, but clearly if they systematically had low returns and high risk they would not have been produced.

[27] We further probe the issue of risk in table A11. In that table we consider the question of whether directors who take risks in other dimensions of film making tend to choose digital. If this type of sorting appears in the data, it will support the idea that the choice of digital may be related to risk taking. We consider all first-time directors, where, as we discuss later, risk taking should be most relevant to career concerns. The analysis shows that across various proxies

Altogether, while there may be other characteristics of new technologies, we may not be able to capture in our setting, we think that differences in ex-ante expertise, expected benefits, and risk are crucial features that help separate the adoption of new technology from other corporate decisions.

3.2 The Main Tradeoffs in Technology Choice

Having introduced the key features of our technology adoption setting, we now discuss how career concerns may affect the likelihood of technology adoption. We present here a qualitative discussion, which we formalize in a simple model in Appendix B. The basic problem we study is the optimal technology choice of a director as a function of her level of experience.

The level of experience should affect a director's adoption problem in two ways. First, managers at different points of their careers will differ in their relative level of familiarity with the two technologies. Experienced directors have already used the old technology and therefore they are relatively more knowledgeable about it (knowledge premium). First-time directors will not have any familiarity with either of the two options, and therefore they will not have any pre-existing advantage with either of the two technologies. This difference in learning costs can influence the relative adoption of new technology across levels of experience. [28]

Second, irrespective of their technological choice, experienced directors are generally more likely to continue working in the future compared to inexperienced directors (continuation advantage). An important feature of our setting is that the careers we are discussing are very risky and the median number of films by new directors is one. In other words, most directors do not survive in

for risk (Z-scores of film categories), first time directors who choose riskier categories of movies tend to adopt digital at a higher rate.

[28] See also an interesting model by MacDonald and Weisbach (2004) which suggests how technology can depreciate the skills of older workers.

the profession after a mediocre performance in their first attempt. However, experienced directors whose work has been successful, are much more likely to continue in the profession (See John et al., 2017, Han and Ravid, 2025).[29]

Thus, the fundamental trade-off in our setting is that experienced directors are more likely to internalize the long-term benefits of the new technology but are also facing relatively higher costs when they switch to the new technology. Obviously, the strength of this mechanism will depend on the size of the "knowledge premium" as we discussed in the previous section, and the relative costs of adoption.

This problem is complicated further if we consider that the choice of technology may influence the likelihood of landing another movie (as modeled in Appendix B). Therefore, directors will not only care about the expected value of the technology, but also about the distribution of returns. In particular, new directors will tend to prefer the new, riskier technology, because the higher risk helps increase the chance that the project will be at the right tail in terms of economic success. We note that the opposite effect will prevail in markets where first-time employees are likely to continue: in this case, agents will be generally more concerned with the downside of the technological choice, therefore actively avoiding new, riskier options. [30]

[29] Conceptually, this discussion is consistent with a standard "career concerns" setting. In these models, a manager's ability is revealed slowly over time (Holmstrom, 1999, MacDonald 1988). Initially, the agent or manager does not know their own ability. Outsiders update their beliefs based on results. Therefore, a "bad project" can damage the reputation of a new manager relatively more than it can damage the reputation of an experienced one. Furthermore, if we assume that low performers are excluded from the industry over time, the pool of experienced managers will be perceived to have higher quality ex-ante, therefore also increasing the ex-ante likelihood of continuation for this group. This is also consistent with models such as Prendergast and Stole (1996) where young managers may take bolder decisions.

[30] If success is also a function of the quality of the agent (director) and it is unknown for first timers, then taking risks, is also consistent with models where agents (or managers and entrepreneurs) are overly optimistic or have better knowledge of this intrinsic quality (e.g., Landier and Thesmar, 2009, or in the context of the movie industry Harris et al., 2017). In these latter models, the subjective distribution looks more promising to agents than it is for uninformed outsiders.

While we formalize the risk argument in Appendix B, a simple numerical example based on a binomial distribution may be sufficient to build intuition. Consider two technologies: a risky technology that has a 70% probability of generating zero revenue and a 30% probability of generating some positive value V; and a safe option that has equal probability of receiving either zero revenues or 0.6V. The two technologies have the same expected revenue, but the riskier technology has a higher variance. If managers must only clear a low bar to continue in the profession (e.g., 0.2V), then the optimal strategy for the director is to use the safer technology, since this gives her a 50% probability of continuing, as opposed to a 30% probability if the riskier technology is adopted. However, if the threshold is high (e.g., 0.8V), then it is optimal for a manager to take the riskier strategy since with the safer strategy the probability of staying in the profession is zero. Note that if we extend this very simple example to a more dynamic model, and assume that the threshold to stay in the profession decreases with the number of movies (which is consistent with the empirical findings that the probability of landing another film is determined by the average rate of return on previous projects – see John et al. , 2017) then it is also true that more experienced managers who by definition will have had a few successful projects already, will tend to become more conservative.[31]

The incentives for risk taking account for the observation that in risky professions such as directing – which, as discussed, has a dropout rate of well north of 70% after the first film, young directors may decide to take the leap into a new and risky technology whereas in a relatively safe profession such as the financial industry (Solomon, 2000; Lamont, 2002; Hong et al., 2000) where the overall probability of termination for analysts is 15%, herding may be optimal for newcomers.

[31] We thank Dawei Fang for this observation.

Thus, our simple framework suggests that experience does not have an unambiguous effect on the adoption of new technologies. Importantly, it is also plausible to expect this trade-off to change overtime. For instance, in light of the previous discussion, we expect first time film makers to choose - everything else equal - the riskier technology. However, this channel is likely to become less important overtime as the new technology matures and becomes less risky.

Given this ambiguity, we now take our predictions to the data. In section 4 we present our empirical analysis. In Section 5, we come back to the framework presented here to discuss the external validity of our results.

4 Adoption of Digital Filming and Director Experience - Evidence

This section describes the empirical strategy and presents the results related to director career concerns and the adoption of digital filming technology. The first part describes the empirical strategy, and the second part presents the main results. The last four sections provide some robustness checks and discuss potential mechanisms.

4.1 Empirical Setting

There are a few features of our setting that make it particularly interesting for testing career concerns models. First, as discussed, movie directors can be viewed as managers in charge of large projects. As a result, the movie industry provides a very natural project-level data set, where both the career of the manager of the project (i.e., the director) as well as all the project's characteristics are available to researchers, and we can discern the career stage of directors adopting the new technology (Cattani and Ferriani, 2008; John et al, 2017; Han and Ravid, 2025).

Second, in a typical organization, the adoption of new technology may reflect both the incentives of a local manager as well as the authority of the headquarters. Our context is much cleaner on this dimension, because of the decentralized project-by-project nature of our data in which directors choose the technology for each film. Furthermore, the incentives of production companies to switch to digital were smaller before the transition to digital projection and the transition to digital technology occurred during a relatively well-defined period of time: thus, we are able to study the entire adoption process, with clear start and end points. As discussed, until the late 1990s there were virtually no digital films, whereas 20 years later there were very few non-digital productions.

To summarize, this context allows us to clearly observe both the decision to adopt and the career of the director; directors are mostly in charge of the adoption decision, and career concerns are extremely salient. With this framework in mind, we estimate a selection model, where we test whether the ex-ante experience of a director enhances her decision to use digital. Our baseline equation is:

$$1\{Digital_{mdt}\} = \alpha_t + \beta Experience_{dt} + \gamma X_{mdt} + \varepsilon_{mdt}$$

where $1\{Digital_{mdt}\}$ is a dummy equal to one if the movie m directed by d in year t was recorded using a digital cinematography, and zero otherwise, α_t is a year fixed-effect, $Experience_{dt}$ is a proxy for the experience of director d in year t, and X_{mdt} are various controls at the movie- or director-level.[32]

In the traditional model of career concerns, the measure of experience captures the extent to which a manager's quality is known. In our context, experience may be measured in several ways. First, we can use the number of feature films directed previously. As we discuss below, this is our preferred and most direct measure. As an alternative, we can also follow the previous literature (e.g., Chevalier and Ellison, 1999a; Hong, Kubik, and Solomon, 2000; Lamont, 2002) and use age

[32] Notice that this equation is estimated with a director-level data set.

as a proxy. However, this measure is not as good in our context, since people start their careers at different ages. Third, we can use a film's budget as a proxy for the level of reputation of the director: the idea is that – all else equal – directors with a stronger reputation will receive larger budgets. This measure is noisy since there are well-known directors such as Spike Lee or Woody Allen, who continue to make relatively low budget films throughout their very successful careers.[33] While experience will be our main variable, later in the paper we will also show that our results hold when we use age and budget as alternative treatments.

There are several other features of this model that we want to highlight. Our main independent variable is the inverse hyperbolic sine (IHS) transformation of the past number of movies directed. We show consistent results with alternative approaches (e.g., non-parametrically defining categories of experience).[34] Second, we estimate the main specification using a linear probability model (LPM) for simpler interpretation of the coefficients, but we also show that the results are qualitatively similar using alternative models (i.e., probit). Third, given our assumption of linearity in the relationship between adoption probability and experience, we reduce the skewness of "experience" by excluding from the analysis directors at the tail of the distribution (i.e., directors with ten or more movies by 1999). Therefore, our main analysis includes movies between 1997

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[33] The choice of using past movie count as our main treatment variable is motivated by both empirical and conceptual reasons. Empirically, a director's history is always observable in our data, unlike other measures. For instance, a film's budget is missing for almost a third of our sample. Conceptually, we think that our measure of experience more directly captures the incentives related to career concerns. Age on the other hand, captures the reputation of a director only indirectly, and largely through its impact on experience (i.e., older directors are systematically more experienced). Budget can potentially capture a director's reputation, but it is also affected by a variety of other characteristics that may be unrelated to this issue (e.g., genre). Furthermore, budget will be potentially affected by the technology choice.

[34] We transform the experience variables for two reasons. First, we find that some form of log-transformation would ease interpretation. Second, the variable experience is skewed (i.e., there are more people with zero or one previous movies). However, because directors with zero experience are important in our analysis, we cannot simply log-transform it. In this context, we have use IHS: this approach is generally preferred to using the traditional log(x+1) approach, since it is better behaved around zero. Note, however, that our results do not depend on the transformation. As we show both graphically and in a regression table, our results also hold when we use a non-parametric approach, where we define experience by defining dummies for individuals with zero.

and 2009 and restricts to directors with less than ten movies by 1999.[35] However, we will show consistent results with the full sample or using a non-parametric approach.

4.2 Main Results

The main question we are trying to answer is whether the level of experience of a director affects the initial wave of adoption of digital filming. Before estimating the regressions, we can test whether any difference can be observed in the raw data without any controls. Figure 2 compares the probability of adopting digital filming across directors with different levels of experience, focusing on the first movie done by a director during the entire first adoption wave (i.e., 1997-2006). For simplicity, we divide directors into four groups depending on the number of movies they had previously directed. The findings are striking. Directors making their first movie (group 0) have a probability of about 10% of using digital technology which is about double that of directors with one (group 1) or two (group 2) previous movies, and three times the probability of adoption of directors with even more experience (group 3).

This effect can be replicated in a regression framework. The main result is presented in Table 2: column 1. We find that higher experience translates into a lower probability of using digital over our sample period. A one-standard-deviation increase in experience translates into a 2% lower probability of doing digital, which corresponds to a roughly 20% decline over the average probability during this period. Across the different columns, we show that results are similar when – in addition to year fixed-effects – we also include controls for genre (column 2) MPAA rating (column 3) or both (column 4).[36] In Table 3, we replicate the same analysis defining experience in

[35] Notice that we also drop movies that are rated as "TV" or "X". We also removed animated movies, since the use of digital was fundamentally different. For obvious reasons, we also exclude a relatively smaller number of movies for which we cannot identify whether they were shot on digital or film cameras because of a lack of data.
[36] The genre is defined by including non-mutually exclusive dummy variables that identify whether the reported list of genres in IMDb lists whether the film is action, drama, comedy, thriller, horror, or other (when this information is

two alternative ways. First, rather than looking at the simple count of past movies, we proxy this dimension with the IHS of the aggregate amount of revenue generated by the director prior to the focal movie. This measure allows us to adjust for experience, weighting previous movies by their level of success.[37] As we show in columns 1 and 2, we find very similar results. In the other two columns, we examine the effect non-parametrically, essentially splitting the sample into four groups based on experience, following the same approach discussed previously for Figure 2. Following the same logic, Appendix Table A1 shows that our same result holds if we weight experience with movie rating (i.e., reviews), using the IMDB rating reported.

In addition to confirming that less experience is generally associated with a higher probability of adoption, this test also gives us a better sense of the relationship between adoption probability and experience. In particular, we find that being a first-time director explains a large part of the transition to digital: on average, first-time directors are more likely to use digital compared to any other group of directors. However, directors with one or two previous movies are still roughly twice as likely to use digital than those with more than two. The same result holds both with and without controls for genre and rating.

Lastly, we also show that this result – early career directors are more likely to adopt – is also confirmed when using the alternative proxies for experience, namely, the director's age or the film budget. In Appendix Table A2, we show that older directors (columns 5 and 6) and directors working on movies with higher budgets (columns 3 and 4) are also less likely to adopt digital. The result holds both in our baseline model and when we include fixed effects to adjust for differences

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missing). As discussed earlier, our analyses also exclude animation movies, for which the meaning of digital is different.

[37] This measure effectively combines intensive and extensive margins in proxying experience. A caveat of this measure is that the revenue is strongly predicted by costs. This is why we generally prefer focusing on past movie count as a better measure of experience and for success one often uses rate of return (See Ravid, 1999, Palia et al, 2008).

in film rating and genre. While we recognize the difficulty of cleanly separating these different dimensions, in Section 4.5 and 4.6 we will further discuss the role of experience relative to age and budget.

4.3 Robustness Tests

This section shows that our results are robust to several alternative specifications. First, we find similar effects when we use a probit model rather than the LPM. Table A3 reports the marginal effects of probit regressions which correspond to the LPM regressions in Tables 2 and 3. Despite the expected differences in magnitudes, the results are qualitatively similar. Second, in Table A4 we show that our results are also almost identical when we exclude movies rated "G." As discussed earlier, there are no digital movies during this early period that are rated "G". This robustness test confirms that this imbalance does not affect our results. In general, few G-rated films are produced each year.

Third, in Table A5, we show consistent results when controlling for past adoption of digital. To adjust to this dynamic dimension, we also include past adoption decision by the director.[38] Although past adoption does predict future adoption, the inclusion of this control does not generally alter our conclusions: if anything, we find a marginal increase in the size of the coefficients. However, this table also supports the idea of higher adjustment costs for experienced directors- the ones who had borne these costs are more likely to continue using digital.

Fourth, we show that our findings do seem to reflect specific career concerns rather than overall industry experience. We collect from IMDB all other credits a director's page shows (for example, she could have been an actor, writer, etc.) and include a variable proxying for previous experience

[38] The control is a dummy equal to one if the director has used digital in the past movie. This variable is zero by construction for first timers.

as a control variable in our analysis. In Table A6, we find very similar effects relative to the baseline.[39] Other prior experience variables seem to have a positive effect on adoption, but this effect becomes insignificant when we add controls. These findings seem to support our framework that views directing a feature film as a unique management position.

Fifth, in Table A7, we consider the full sample of directors, also including directors with an exceptional level of experience. This inclusion slightly increases the overall sample, but again, it does not significantly affect our magnitude or statistical significance.

4.4 Structural Changes in the Market

We now examine the timing of our effects. In particular, we divide the sample period into three parts: (1) before 2002, when digital productions were extremely rare; (2) between 2002 and 2006, when digital productions were still a small (but growing) fraction of all movies, but the technology was starting to be adopted more broadly; (3) and after 2006.

The last period is of particular interest. As noted in Section 2.1, the financial advantages of shooting digitally rose sharply after 2006, spurred by a deal between the studios and theaters that significantly accelerated the adoption of digital projectors, easing the distribution of digitally shot films. If financial incentives, such as studio pressure on inexperienced directors, were the primary drivers of our estimates, we would expect a rising trend over time. Conversely, a career concerns mechanism would imply, as discussed earlier, that experienced directors would adopt in large numbers as the benefits of digital increase.

[39] To be precise, this variable counts all the credits reported in the data, excluding the credit as directors (which relates to our main treatment) and the acknowledgments (i.e., thanks from other directors or producers). Examples of activities that are normally reported in the credits are writer, producer, editor, decorator, among the others. For consistency with the rest of the analysis, this variable is transformed using the inverse hyperbolic sine transformation.

The results of this analysis are reported in Table 4: in particular, we report separately the coefficient of our main treatment effect across the three periods. We find that the effect of experience is completely driven by the initial phase of large-scale adoption between 2002 and 2006.[40] After 2006, the effect is smaller in size and not significantly different from zero. This evidence is consistent with our conceptual framework discussed before. In fact, this result suggests that the gap in adoption rates is related to experience only during the early phase of the technology adoption cycle, when the uncertainty and the risk related to digital were high. The special nature of the early period of adoption (i.e., 2002-2006 in our case) is also supported by the survey we ran among members of the Directors Guild of America. We asked about reasons for choosing to shoot digital on the one hand and concerns with adoption on the other hand. The most salient finding is that the period between 2002 and 2006 was different than any period before or after.

Altogether, this set of results seems to imply that career considerations were important for the adoption of digital filming and the findings are consistent with our conceptual discussion. On average, more experienced directors were less likely to adopt the new technology, and this effect is not explained by differences in the type of movie, as well as other confounding factors. Much of the effect manifests in the difference between directors making their first movie versus the rest, and experience appears less important as directors become more experienced.

4.5 Experience and Technology Expertise

Before we discuss possible alternative mechanisms that may explain our results, we want to briefly discuss the role of technical expertise in adoption decisions. Our data enables us to consider

[40] We also find a null effect on the first period: we are not surprised by this result, since this period has very few digital movies in our sample (around 3%). We include it to provide a benchmark or "pre-period" to the time when adoption has actually significantly increased.

precisely whether general technical proficiency makes a difference for technology adoption. We should keep in mind that most directors, new or old, had no experience in digital technology per se, but since most directors had accrued previous industry experience, then those who had worked in some technical capacities should have been more adept with new technology.[41]

We conduct this analysis in Table 5, adding controls for technical expertise (columns 1 and 2). We find that technical expertise does have a significant positive impact on the probability of adopting digital technology. This supports the idea that our measure of expertise captures a significant dimension of a director's skill set. However, our main effects remain qualitatively and quantitatively unchanged: while technical expertise matters, this channel seems to run parallel to the channel based on experience.

In column 3, we test for differential effects of the career variables depending on the level of technical expertise. The idea is that – to the extent that the heterogeneity in behavior comes even just in part from differences in technical expertise – we should find that our effects should be higher for the more technically skilled. However, our results reject this hypothesis.

The idea that even when we consider technical expertise career concerns play a major role in technology choice, is confirmed by an analysis that focuses on a sample of directors who had not been exposed to digital technology in film school or during early training in the industry. Appropriate film school training in digital technology may make the cost of adoption lower for digitally trained directors relative to directors who were trained in film.

[41] We define a director to be more technically skilled, if he had experience on technical roles within the movie industry. Using data on the director's IMDb page we look at whether the director had previous work in the following roles: (1) camera and electrical department; (2) cinematographer; (3) special effects; (4) visual effects.

One way to explore this dimension is to use the age of a director, and in particular focus only on directors who are less likely to have studied digital technology in film school. This analysis also helps us separate age from experience and focuses on directors where the cost of switching to digital may be more comparable. We argue that experience and career concerns matter rather than age. In other papers age is used as a proxy for experience, but here we have a way to separate the two. In Table 6, we focus specifically on the subset of directors who were forty years or older in 2000.[42] This sample is much smaller than the main one, but we still find results that are consistent with our previous results, albeit less precisely estimated in some specifications. These findings suggest that the preferences for digital production are not because of education. Also, while we recognize that separating age and experience is challenging both empirically and conceptually, it seems that the adoption decision reflects experience rather than just older age. This strengthens our career concerns interpretation and contributes to the literature that often has to contend with using age as a proxy for professional experience.

4.6 Alternative explanations

This section considers some further alternative explanations for our results. Conversations with industry insiders suggest that budgets and other movie related strategies are subject to give and take between studios and directors (much in the same way that CEOs have conversations with boards and activist shareholders). It may then be that studios prefer digital shooting, and their ability to impose their preference on the creative team is greater when that team is led by an

[42] Forty years also corresponds to roughly the median age in our sample. This analysis also drops those directors for whom we cannot confirm the birth year. Notice that birth year was missing for a significant number of directors from IMDb. To supplement this information, we manually searched directors on Wikipedia. Ultimately, we were able to identify the birth year for almost 60% of the directors in our sample.

inexperienced director. However, the implication of this statement does not align with the timing of the effects we show.

As discussed earlier, the economic benefit of using digital cinematography increased over time, and it was particularly high after 2007, when digital movies could be distributed directly without converting to film (Section 2). Also, the technology was improving by leaps and bounds and would be much more appealing later in the sample period. Therefore, if our results were to reflect differences in bargaining power between a director and producers, we should expect the "inexperienced director" effect to become larger – rather than disappear – later in the sample period. Therefore, the timing of our results appears at odds with this interpretation (Table 4).

We further reject this concern by studying how a director's outside options matter for adoption. If our results simply reflected bargaining between the director and the producers, we should expect that other proxies for the bargaining power of the director would (negatively) predict adoption. A clean way of examining this hypothesis is by focusing on directors making their first feature film and then testing whether their previous activity in the industry predicts their use of digital technology. The intuition for this test is the following: if the bargaining between the studios and director is a relevant variable in explaining our findings, we should find less digital adoption for people who had had many industry credits prior to directing their first film, for example, well-known actors or writers, everything else equal.[43]

We present these results in Table A8. To proxy a first-time director's outside options, we use both the number of total IMDB credits prior to their debut as a director (columns 1 and 2), as used before, as well as the number of credits as an actor or actress (columns 3 and 4). This second

[43] For instance, we should expect that Ben Affleck had more bargaining power when directing his first movie than another person with less cinematic experience.

measure aims to capture the relatively common case of a famous actor starting to direct later in her career. A famous actor is exactly the type of first-time director, who has no reputation as a feature film director – and therefore may face career incentives as discussed – but is still likely to have ex-ante bargaining power with respect to production given their prominence in the industry. We find that both measures of bargaining power do not predict differential adoption, and this is true both when we use a continuous variable (odd columns) or a dummy variable capturing those directors in the top quartile of this measure.[44]

Another possibility is that a director's experience may influence the budget, which in turn may affect the type of recording technology used. In fact, inexperienced directors tend to have tighter budgets, and this condition may systematically lead them to use digital technology. Isolating budget from experience is challenging. First, directors with more experience tend to systematically direct movies with larger budgets and budget may in itself proxy for reputation and experience (Table A2). However, this is not always the case. There are well-known directors such as Woody Allen and Spike Lee who have been working for decades on movies with relatively modest budgets, due to the nature of their narratives. Second, budget is endogenous to technology choice. Production and distribution costs may differ by technology. Third, budget data is missing for a substantial number of movies in our sample.[45]

Despite these constraints, we try to address this issue in several ways. Conceptually, as discussed earlier, if financial incentives drove technology choices, then the effect should have intensified rather than disappeared after 2006 (Table 4)[46]. Empirically, we can conduct two additional useful

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[44] We thank Yakov Amihud for suggesting this test.
[45] As we were able to check manually, budget is generally available for larger productions, while it may be missing for smaller projects.
[46] Also, the cost of film or equipment in general is not paramount for the typical production considered in this study.

exercises. First, we try to test whether our findings simply reflect differences between projects without any significant budget constraints versus movies where financial trade-offs may be more relevant. To do this, we replicate our main results by removing large productions, defined as movies with a confirmed budget above $50M. Results in Table 7 show that despite the smaller sample size, our findings remain largely unchanged. This suggests that our estimated experience effect does not simply reflect differences in the prevalence of experienced directors who direct big-budget movies.

Second, we focus on the set of directors with the strongest career concerns – first time directors – and compare their propensity to use digital relative to other directors with similar budgets but slightly greater reputation (i.e., directing their second movie) during the core period in our adoption wave (i.e., 2002-2006). The idea is to focus on the sample where career concerns' effects are the most significant, and test if our results still hold when shutting down variation in budget by including a narrow set of fixed effects that divides the movies considered in ten groups by budget, also interacted with year dummies.[47] The results are presented in Table A9: similar to our baseline findings, first-time directors are characterized by a 5% higher probability of using digital relative to another director with one movie of under their belt, producing a movie with a similar budget in the same year.

Lastly, we would also like to discuss the possibility that directors with different levels of experience may prefer digital versus film simply because they tend to direct different types of movies or have preferences for different types of digital content. One may be concerned that the style of filmmaking of inexperienced directors – particularly first timers – may be different in ways

[47] In particular, the ten groups are created as a combination of nine equally sized groups plus one group for movies with missing budget. The equally sized groups are created on the exact sample used in the analysis.

that would require more extensive use of digital filming. For instance, inexperienced directors may focus on making movies that require more special effects, which in turn makes them more likely to benefit from digital filming for reasons that are orthogonal to career concerns.

We consider this hypothesis by comparing movies that were shot digitally to others that had been recorded originally on film but were later transferred into digital forms in post-production ("digital intermediary"). The idea of this test is the following: during our sample period, a director who wanted to shoot a movie on film but still wanted to take advantage of digital technologies to include special effects of various forms could do this by adding an intermediate digital transfer of the movie. In other words, directors could transfer the movie (or part of it) into digital format, undertake all the intermediate steps in this format, and then move it back to film for distribution. Importantly, this "digital intermediate" technology was already used at the end of the 1990s and it did not present the same risks as shooting directly in digital, since the original material was always available in film.

Leveraging this feature, in Table A10 we compare movies that were shot digitally to other movies that were not shot digitally but that undertook a digital intermediate step during production.[48] These two sets of movies should be more comparable than the entire population of movies since they both can access the same type of post-production features. When focusing on this sub-sample, we still confirm our main results. If anything, the magnitude of the effects is now larger. We should note that this test may not be as definitive as we would like it to be because depending on the intended projection technology movies would have to be ultimately converted to either film (before the widespread use of digital projectors) or to a digital format (when most projectors were

[48] Data on whether a film used a digital intermediate is also included in the technical specifications section of the IMDb page that we used to categorize the movie cameras as either digital or film.

digital). The period between 2002 and 2006 when most the “action” happens in our data was an intermediate period, so we believe this test, that reinforces our results is useful.

To summarize, the above discussion helps us rule out several leading alternative interpretations to our career concerns hypothesis. Our findings that differential adoption is based on experience in directing generally holds even if we include other possible mechanisms such as variation in technical expertise, financial slack, pressure from production companies, or movie type.

5 Discussion

The empirical evidence in the previous section shows that career concerns may affect the incentives to adopt a new technology. We find that the first adoption wave of digital cinematography in the motion picture industry was largely driven by inexperienced directors. This suggests that early career managers may play a particularly important role in the propagation of new technologies in the workplace. However, we also see that as parameters change, and the new technology becomes less risky and more valuable, more experienced directors are more likely to adopt (i.e., the continuation benefits seem to be more pertinent).

Considering the framework discussed in Section 3, this result can be explained by two non-mutually exclusive mechanisms. First, the long-term benefits of adopting earlier were not sufficiently high to compensate for the higher cost (or lower benefits) of switching to digital among experienced directors. This hypothesis is plausible in this setting, because the movie industry is characterized by large and infrequent projects. Therefore, a director that does not adopt immediately is likely to be able to switch to digital later, if the value of switching is high. In this context, the early adoption benefits are limited and the cost of learning a new technology may significantly reduce the incentives of experienced directors to adopt digital.

Second, the risk-taking incentives for early career directors were sufficiently strong. This mechanism also appears plausible. As discussed in John et al. (2017) and Han and Ravid (2025) and confirmed in our data, the market for feature film directors is extremely competitive, and early career directors can continue directing feature films only if they are extremely successful. Furthermore, in evidence discussed earlier (Table A11), we find that preferences for riskier movies appear also to be correlated with choosing digital. In this context, we should expect inexperienced directors to have a strong incentive to be risk-takers, which is exactly what we find. In other words, the "cut-throat" nature of the industry should favor the adoption of the riskier option. The comparison to Hong et al. (2000) is particularly interesting: in the context of analysts' career where the threshold for continuation is low, we see herding, whereas in our case, where the majority of first-time directors drop out, risk-taking is encouraged.

If risk-taking is an economically important mechanism, we should expect the distribution of career outcomes for directors who have chosen digital to have "fatter tails" than the distribution of outcomes for directors who have chosen film. Testing this hypothesis is not easy because we do not have a clear way to isolate exogenous variation in digital adoption, making it difficult to separate the impact of technology adoption from selection. However, with this important caveat in mind, Table 8 compares how the choice of digital among first-time directors affects their future careers.

Consistent with our hypothesis, we find that first-timers who choose digital tend to experience both extreme career outcomes. On the negative side, directors who chose digital are less likely to direct a second movie (columns 1 and 2). This evidence reflects some of the downside risk associated with digital in the early adoption phase. On the positive side, however, the choice of digital appears linked to a greater likelihood of producing a highly successful movie. Specifically, first-time directors who chose digital are more likely to have their movie rank in the top decile of financial returns (columns 3 and 4). Since financial success can enhance a director's bargaining power and future opportunities, this suggests that—in some cases—the digital choice paid off. Lastly, and also consistent with our framework, we find that choosing digital early on is associated with a significantly higher likelihood of using digital in future projects (columns 5 and 6).[49] With all caveats discussed before, the presence of polarized outcomes in the careers of directors that adopted digital earlier is consistent with our hypothesis about the importance of technology risk in this setting.

Before concluding, it is important to discuss the external validity of our results. In general, this discussion about mechanisms is important because it can also help us think about what to expect in other industries. A particularly interesting dimension is the nature of competition for promotions. In many highly competitive fields, it is reasonable to expect that the need to "stand out from the crowd" can generate a strong incentive for newcomers to adopt new technologies or business methods, similar to our findings on film directors. For instance, Levy (2005) finds that "careerist judges" tend to be creative, contradicting previous decisions more often, to build a reputation. By the same token, Bowen et al. (2017) show that the adoption of new empirical techniques among academics in finance is driven by early careers. However, the same mechanism will not apply in areas where the career progression is more linear and the bar to clear for promotion is low, perhaps public administration. In several developed countries career progression in the public sector is mostly tied to tenure. In this situation, managers may prefer "to play it safe"

[49] There are two other limitations in this analysis. First, data on returns is missing for a significant set of movies, largely because of missing budget information (as discussed earlier). Second, our measure of returns is based on publicly available data on budget and worldwide theatrical gross sales. While being the best measure available, this may not fully capture the cost and revenue generated by a movie. We also point out that the drop in observation count in columns 5 and 6 is due to the fact that this analysis is conditional on having directed another movie.

or “herd” and avoid taking any initiative that can generate downside risk, irrespective of the upside that can be captured.

In our view, there are three takeaways from this discussion. First, regardless of the specific mechanism, our results suggest that the type of career progression and the mix of early career and more experienced employees may critically affect technology adoption in any industry. These factors may explain why organizations differ in their propensity to adopt new technologies, and why technology adoption may be slow, even when external frictions are limited.

Second, we believe that outcomes are tied to the risk of separation (firing) in an industry and the value of early adoption. In contexts where the level of competition in the labor market is fierce; and the long-run benefits of early adoption are more limited, for instance, many artistic or intellectual professions our results are more likely to hold.

Third, we also want to recognize that – outside these areas – the relationship between career concerns and technology adoption remains still ex-ante ambiguous. In these cases, a detailed analysis of the competitive landscape is helpful in assessing the types of frictions that career concerns may generate.

Section 6 Conclusion

This paper studies how career concerns may affect the adoption of new technologies. To examine this question, we focus on the adoption of digital technology in the motion picture industry and present a simple conceptual framework showing how our findings may extend outside this context.

In the first decade of the twenty-first century there was a dramatic shift in the technology used in films. Focusing on this period, we find that inexperienced directors played an important role in this transition. This effect does not appear to be explained by differences in the movie genre, rating, or technical expertise. We argue that this relationship can be explained by career concerns rather than other mechanisms, such as differences in funding, bargaining power, or preferences for digital content between more and less experienced directors.

At face value, these results suggest that managers in their early career may play a particularly important role in the propagation of new technologies in the workplace (which is conceptually similar to Acemoglu et al., 2022). However, we also want to highlight how our conceptual framework suggests that this relationship is likely to be context dependent.

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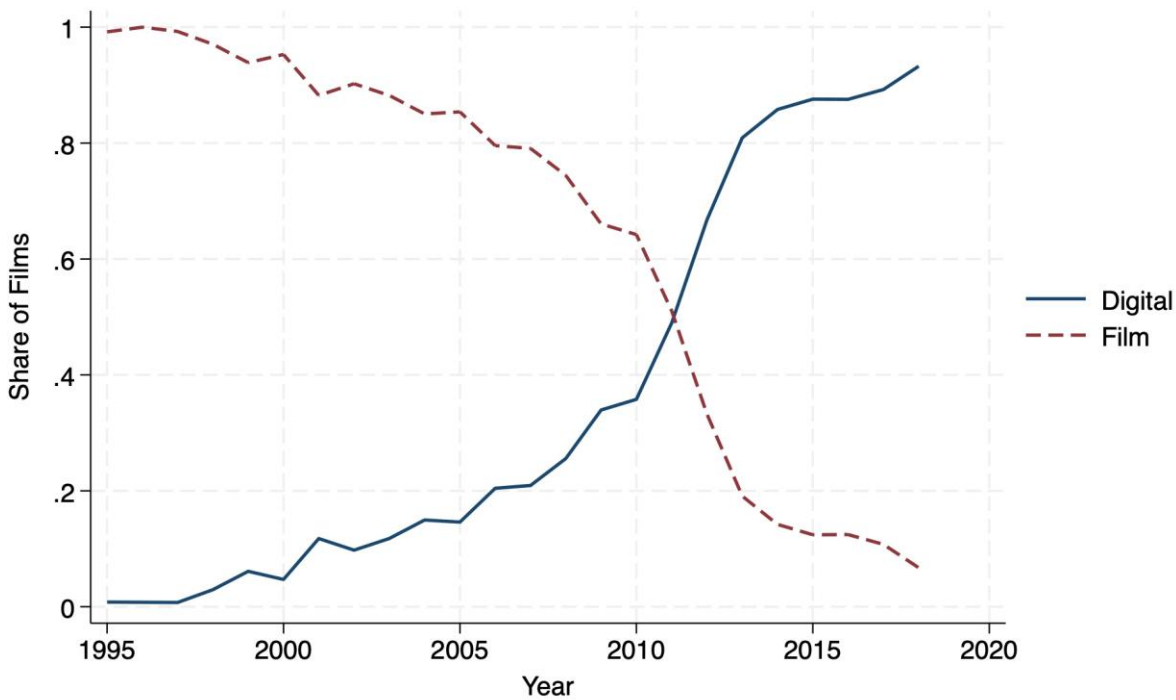
Figures

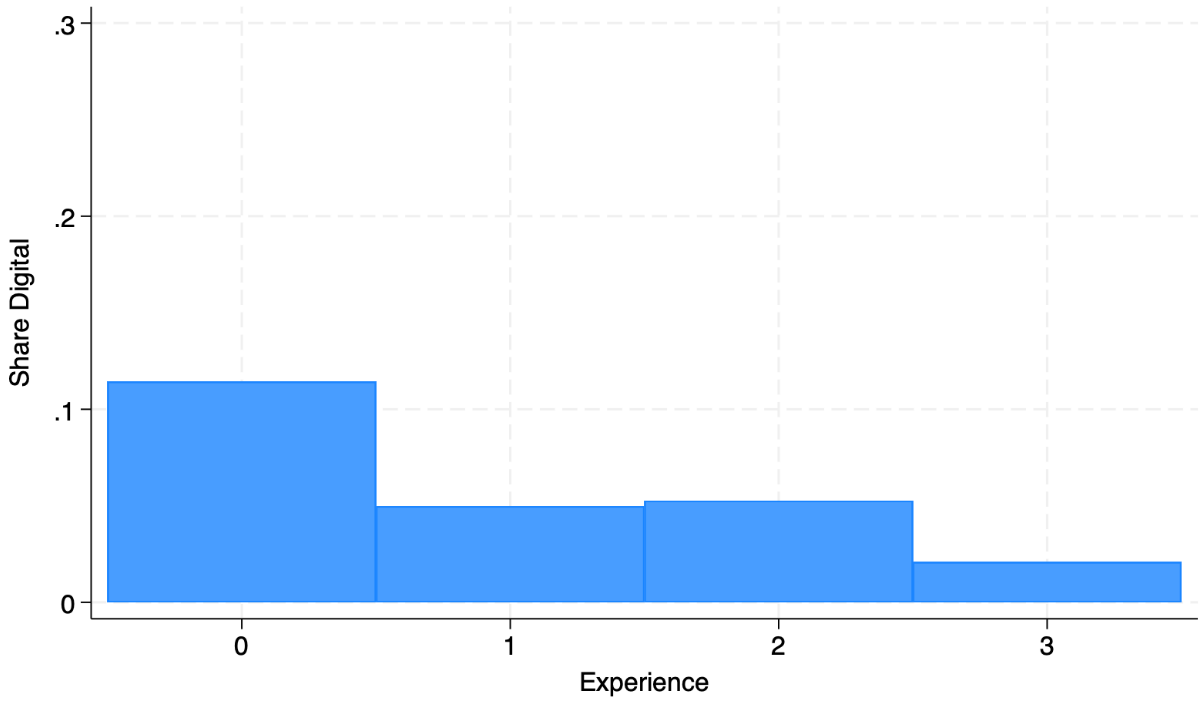
Figure 1: Share of Movies with Digital Cinematography.



Notes: this figure reports the share of films that were categorized as being films with either a digital or film camera in a year (sample period 1995-2018). A film was categorized using the "Technical Specifications" information on the film's IMDb page.

Alt Text: Line graph showing the share of movies shot digitally versus on film from 1995 to 2018. Digital adoption is near zero in the late 1990s, increases gradually in the early 2000s, accelerates sharply after 2007, and exceeds 90% by 2018, displaying a classic S-shaped diffusion pattern.

Figure 2: Share of Digital Films by Experience



Notes: this figure reports the probability that a director will choose a digital camera conditional on different levels of previous experience, focusing on the first movie done by the director in early adoption phase (i.e., 1997-2006). Group 0 are directors that have directed no previous films. Group 1 are directors with one previous film. Group 2 are directors with two previous films. Groups 3 are directors with more than two previous films.

Alt Text: Bar chart comparing the probability of using digital cinematography across directors grouped by prior experience, focusing on the first movie done during the early digital adoption period (i.e., 1997-2006). First-time directors have the highest adoption rate (around 10%), roughly double that of directors with one or two prior films, and about three times that of directors with more experience, showing that digital adoption declines sharply with experience.

Tables

Table 1: Standard Deviation of Film Returns

Period		**1998-2009**	**2001-2009**	**Winsor 1998-2009**	**Winsor 2001-2009**
G	SD Film	4.71	5.53	4.71	5.53
	SD Digital	NA	NA	NA	NA
PG	SD Film	8.91	9.80	3.06	3.45
	SD Digital	48.96	49.97	8.12	9.73
PG13	SD Film	4.76	5.14	2.93	3.23
	SD Digital	4.87	4.87	4.54	4.87
R	SD Film	122.80	15.54	3.80	4.08
	SD Digital	1031.82	1055.78	5.58	6.11
Unrated	SD Film	6.47	6.79	4.08	4.67
	SD Digital	9.39	9.63	5.95	6.63

Notes: this table reports the standard deviation of move returns for each camera type by film rating and time period. Film returns are defined as the difference between worldwide gross revenue and the budget relative to the budget, as reported in IMDb. The last two columns winsorize the data at the top and bottom one percent.

Table 2: Probability of Adoption (Baseline Results)

	(1) digital	(2) digital	(3) digital	(4) digital
# Previous films (IHS)	-0.017***	-0.017***	-0.012**	-0.012**
	(0.005)	(0.005)	(0.005)	(0.005)
Genre F.E.	No	Yes	No	Yes
Rating F.E.	No	No	Yes	Yes
Observations	3766	3766	3766	3766
Adjusted R^2	0.058	0.059	0.070	0.073

Notes: year fixed effects included, robust errors in parenthesis. This table reports the results from the main specification. The outcome is a dummy for whether the director used a digital or film camera. The main variable of interest is the inverse hyperbolic sine of the number of previous movies the director had directed.
* p<0.10, ** p<0.05, *** p<0.01

Table 3: Probability of Adoption (Alternative Measures of Experience)

	(1) digital	(2) digital	(3) digital	(4) digital
Previous Movie Revenue (IHS)	-0.009***	-0.005**		
	(0.002)	(0.002)		
Only One Prev. Movie			-0.046***	-0.039***
			(0.014)	(0.014)
Only two previous movies			-0.071***	-0.060***
			(0.016)	(0.016)
>2 Prev. Movies			-0.045***	-0.031**
			(0.013)	(0.013)
Genre F.E.	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes
Observations	3766	3766	3766	3766
Adjusted R^2	0.059	0.073	0.061	0.075

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for two alternative measures of director's past experience. Columns 1 and 2 include the cumulative gross revenue of past movies. Columns 3 and 4 consider a non-parametric measure of experience using bins of total previous films. The outcome is a dummy for whether the director used a digital or film camera.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 4: Probability of Adoption (Effect Over Time)

	(1) digital	(2) digital
Prev. Films X 1997-2001	-0.005	0.002
	(0.005)	(0.005)
Prev. Films X 2002-2006	-0.037***	-0.030***
	(0.008)	(0.008)
Prev. Films X 2006-2009	-0.002	0.001
	(0.014)	(0.014)
Genre F.E.	No	Yes
Rating F.E.	No	Yes
Observations	3766	3766
Adjusted R^2	0.060	0.075

Notes: year fixed effects included, robust errors in parenthesis. This table reports the estimated effect of experience for different time periods. The outcome is a dummy for whether the director used a digital or film camera. The main variable of interest is the inverse hyperbolic sine of the number of previous movies the director had directed interacted with the time period in which the movie was directed.

Table 5: Probability of Adoption (Controlling for Previous Technical Expertise)

	(1) digital	(2) digital	(3) digital
# Previous films (IHS)	-0.015***		-0.016***
	(0.005)		(0.006)
Only One Prev. Movie		-0.038***	
		(0.014)	
Only two previous movies		-0.061***	
		(0.016)	
>2 Prev. Movies		-0.038***	
		(0.013)	
Technical Expertise=1	0.078***	0.076***	0.072***
	(0.013)	(0.013)	(0.021)
Technical Expertise=1 # # Previous films (IHS)			0.005
			(0.013)
Genre F.E.	Yes	Yes	Yes
Rating F.E.	Yes	Yes	Yes
Observations	3766	3766	3766
Adjusted R^2	0.084	0.085	0.083

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results controlling for a director's past experience in the technical production of films. Data on a director's technical expertise is taken from the "Filmography" section of the director's IMDb page. The technical expertise variable is a dummy that is equal to 1 if the director was listed as being in the "Camera and Development", "Cinematographer", "Special Effects", or "Visual Effects" departments on a previous film. Column 1 uses the inverse hyperbolic sine of the number of previous movies whereas column 2 uses dummy bins for the number of previous movies. Column 3 includes the interaction between past experience and past technical expertise. The outcome is a dummy for whether the director used a digital or film camera.

Table 6: Probability of Adoption (Restricting to Directors At Least 40 Years Old in 2000)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.015**	-0.013*				
	(0.007)	(0.007)				
Previous Movie Revenue (IHS)			-0.005**	-0.003		
			(0.003)	(0.003)		
Only One Prev. Movie					-0.048**	-0.045**
					(0.021)	(0.021)
Only two previous movies					-0.036	-0.029
					(0.024)	(0.024)
>2 Prev. Movies					-0.048***	-0.043**
					(0.018)	(0.019)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	1658	1658	1658	1658	1658	1658
Adjusted R^2	0.042	0.052	0.041	0.050	0.043	0.052

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification restricting to directors that are at least forty years old. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table 7: Probability of Adoption (Excluding Major Projects)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.019***	-0.014**				
	(0.006)	(0.006)				
Previous Movie Revenue (IHS)			-0.010***	-0.006**		
			(0.002)	(0.003)		
One Prev. Movie					-0.042***	-0.034**
					(0.015)	(0.015)
Two Prev. movies					-0.062***	-0.049***
					(0.017)	(0.017)
>2 Prev. Movies					-0.047***	-0.036**
					(0.014)	(0.014)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3264	3264	3264	3264	3264	3264
Adjusted R^2	0.053	0.072	0.055	0.073	0.055	0.074

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results excluding from the sample the major motion picture projects. Excluded films must have a confirmed (non-missing) budget above $50 million. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table 8: The Effects of Choosing a First Digital Film on Director Career

	(1) Second Movie	(2) Second Movie	(3) Top Movie	(4) Top Movie	(5) Any Other Digital	(6) Any Other Digital
Digital	-0.065*	-0.067*	0.097***	0.087**	0.262***	0.260***
	(0.035)	(0.035)	(0.036)	(0.036)	(0.066)	(0.067)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	No	No	Yes
Observations	1470	1470	984	984	568	568
Adjusted R^2	0.041	0.057	0.014	0.028	0.045	0.053

Notes: year fixed effects included, robust errors in parenthesis. This table examines the effect of adopting digital on the sample of first-time movie directors (i.e., directors with no previous movies). The treatment variable Digital is one if the director used digital in the first movie. In columns 1 and 2 the outcome is a dummy equal to one if the director has done a second movie as director after the first one. In columns 3 and 4, the outcome is a dummy equal to one if the first movie is in the top decile of movie returns in the sample. Returns are defined based on reported budget and worldwide reported gross revenue, and this variable is not available for all movies. In columns 5 and 6, the outcome is a dummy equal to one if any of the following movies directed is digital, and this is estimated only on the sub-sample of directors that have directed more movies after the first. Odd columns include only year fixed-effects, while even columns also include genre and rating. * p<0.10, ** p<0.05, *** p<0.01

Online Appendix for
"Technology Adoption and Career Concerns: Evidence from the Adoption of Digital Technology in Motion Pictures"

By Grant Goehring, Filippo Mezzanotti, S. Abraham Ravid

Appendix A: Additional Tables

Table A1: Probability of Adoption (robustness to weighting previous films by reviews)

	(1)	(2)
	digital	digital
# Previous Films Weight by Reviews (IHS)	-0.011***	-0.008**
	(0.003)	(0.003)
Year F.E.	Yes	Yes
Genre F.E.	No	Yes
Rating F.E.	No	Yes
Observations	3766	3766
Adjusted R^2	0.058	0.074

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification where the treatment is a measure of experience weighted by users' reviews (IMDB). This measure is essentially the sum of past reviews on movies, which is transformed using inverse hyperbolic sine as in the main analysis. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A2: Probability of Adoption (robustness to different director experience definitions)

	(1)	(2)	(3)	(4)	(5)	(6)
	digital	digital	digital	digital	digital	digital
# Previous films (IHS)	-0.017***	-0.012**				
	(0.005)	(0.005)				
Budget (IHS)			-0.041***	-0.047***		
			(0.005)	(0.006)		
Age (IHS)					-0.076***	-0.060***
					(0.022)	(0.022)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3766	3766	2976	2976	3454	3454
Adjusted R^2	0.058	0.073	0.098	0.110	0.053	0.071

Notes: year fixed effects included, robust errors in parenthesis. This table presents robustness where we estimate our main empirical specification using different definitions of director experience. Columns 1 and 2 use the inverse hyperbolic sine of previous films, our preferred measure of experience. Columns 3 and 4 use the inverse hyperbolic sine of film budget. Columns 5 and 6 use the inverse hyperbolic sine of director age. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A3: Probability of Adoption (Main Specification Using Probit)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.018***	-0.013**				
	(0.005)	(0.005)				
Previous Movie Revenue (IHS)			-0.009***	-0.005**		
			(0.002)	(0.002)		
Only One Prev. Movie					-0.047***	-0.039***
					(0.014)	(0.014)
Only Two Prev. Movies					-0.073***	-0.064***
					(0.018)	(0.018)
>2 Prev. Movies					-0.045***	-0.032***
					(0.012)	(0.012)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3766	3757	3766	3757	3766	3757

Notes: year fixed effects included, robust errors in parenthesis. This table presents the marginal effects of the main specification estimated using probit instead of a linear probability model. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A4: Probability of Adoption (Dropping G Rated movies)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.017***	-0.011**				
	(0.005)	(0.005)				
Previous Movie Revenue (IHS)			-0.008***	-0.005**		
			(0.002)	(0.002)		
Only One Prev. Movie					-0.046***	-0.039***
					(0.014)	(0.014)
Only Two Prev. Movies					-0.071***	-0.059***
					(0.016)	(0.016)
>2 Prev. Movies					-0.044***	-0.031**
					(0.013)	(0.013)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3732	3732	3732	3732	3732	3732
Adjusted R^2	0.057	0.073	0.059	0.073	0.060	0.075

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification dropping the sample of films that are rated G. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera.
* p<0.10, ** p<0.05, *** p<0.01

Table A5: Probability of Adoption (Controlling for Past Adoption)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.028***	-0.022***				
	(0.005)	(0.005)				
Previous Movie Revenue (IHS)			-0.011***	-0.008***		
			(0.002)	(0.002)		
Only One Prev. Movie					-0.062***	-0.055***
					(0.014)	(0.014)
Only two previous movies					-0.086***	-0.075***
					(0.016)	(0.016)
>2 Prev. Movies					-0.066***	-0.054***
					(0.012)	(0.012)
1{Past Adopt}	0.321***	0.312***	0.314***	0.305***	0.321***	0.313***
	(0.044)	(0.043)	(0.043)	(0.042)	(0.043)	(0.042)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3766	3766	3766	3766	3766	3766
Adjusted R^2	0.091	0.104	0.091	0.103	0.094	0.107

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification controlling for whether the director had previously adopted digital filming. The past adopt variable is a dummy for whether any of the director's previous films were filmed using a digital camera. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera.

* p<0.10, ** p<0.05, *** p<0.01

Table A6: Probability of Adoption (Controlling for Other Experience)

	(1) digital	(2) digital	(3) digital	(4) digital
# Previous films (IHS)	-0.023***		-0.016***	
	(0.006)		(0.006)	
Only One Prev. Movie		-0.049***		-0.041***
		(0.014)		(0.014)
Only two previous movies		-0.077***		-0.064***
		(0.016)		(0.016)
>2 Prev. Movies		-0.056***		-0.040***
		(0.013)		(0.014)
# Prev. Credits (IHS)	0.010**	0.009**	0.008	0.007
	(0.005)	(0.005)	(0.005)	(0.005)
Genre F.E.	No	No	Yes	Yes
Rating F.E.	No	No	Yes	Yes
Observations	3766	3766	3766	3766
Adjusted R-squared	0.058	0.061	0.073	0.076

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification where we also include a control for the number of other credits as a control. This variable is transformed as usual using the inverse hyperbolic sine transformation. The different columns present the results for the two alternative measures of a director's past experience: continuous (columns 1 and 3) and discrete (columns 2 and 4). Columns 3 and 4 contain extra controls, as reported. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A7: Probability of Adoption (Results Using the Full Sample)

	(1) digital	(2) digital	(3) digital	(4) digital	(5) digital	(6) digital
# Previous films (IHS)	-0.016***	-0.010**				
	(0.005)	(0.005)				
Previous Movie Revenue (IHS)			-0.008***	-0.004**		
			(0.002)	(0.002)		
Only One Prev. Movie					-0.046***	-0.039***
					(0.014)	(0.014)
Only two previous movies					-0.071***	-0.060***
					(0.016)	(0.016)
>2 Prev. Movies					-0.045***	-0.031**
					(0.012)	(0.012)
Genre F.E.	No	Yes	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes	No	Yes
Observations	3937	3937	3937	3937	3937	3937
Adjusted R^2	0.060	0.075	0.061	0.075	0.063	0.078

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification for the full sample of directors. This includes exceptional directors with ten or more previous films directed. The different columns present the results for the three alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use the cumulative revenue of past directed films. Columns 5 and 6 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A8: Probability of Adoption among first-timers as a function of previous industry experience.

	(1) digital	(2) digital	(3) digital	(4) digital
# Prev. Credits (IHS)	-0.001			
	(0.008)			
Top (quart) Prev. Credits		-0.011		
		(0.026)		
# Actor Credits (IHS)			0.001	
			(0.006)	
Top (quart) Actor Credits				-0.024
				(0.022)
Genre F.E.	Yes	Yes	Yes	Yes
Rating F.E.	Yes	Yes	Yes	Yes
Observations	1470	1470	1470	1470
Adjusted R-squared	0.084	0.084	0.084	0.084

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results where we examine how the probability of adopting is a function of a director's outside options, among first-time directors. Outside options are proxy with the total number of film credits (excluding credits as director and thanks) in columns 1 and 3, and the total number of credits as an actor in columns 3 and 4. These variables are included as continuous measures transformed using the inverse hyperbolic sine in columns 1 and 3, and as a dummy equal to one if a director is in the top quartile within the main sample used in the paper in columns 2 and 4. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A9: Probability of Adoption Controlling for Budget Decile by Year Fixed Effects

	(1)	(2)
	digital	digital
First Movie	0.061**	0.053**
	(0.024)	(0.024)
BudgetXYear F.E.	Yes	Yes
Genre F.E.	No	Yes
Rating F.E.	No	Yes
Observations	873	873
Adjusted R^2	0.091	0.102

Notes: Robust errors in parenthesis. The sample restricts to observations where the director has either no previous films or one previous film. First Movie is a dummy for whether the film is a director's first film. The regressions control for budget by adding budget decile by year fixed effects. The outcome is a dummy for whether the director used digital or film. * p<0.10, ** p<0.05, *** p<0.01

Table A10: Comparing Digital vs. Digital Intermediary

	(1) digital	(2) digital	(3) digital	(4) digital
# Previous films (IHS)	-0.062***	-0.042***		
	(0.012)	(0.012)		
Only One Prev. Movie			-0.146***	-0.115***
			(0.034)	(0.034)
Only two previous movies			-0.203***	-0.167***
			(0.036)	(0.036)
>2 Prev. Movies			-0.165***	-0.114***
			(0.029)	(0.030)
Genre F.E.	No	Yes	No	Yes
Rating F.E.	No	Yes	No	Yes
Observations	1435	1435	1435	1435
Adjusted R^2	0.063	0.109	0.073	0.116

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results with films that were not shot digitally but undertook a digital intermediary post-production process. The different columns present the results for the two alternative measures of a director's past experience. Columns 1 and 2 use the inverse hyperbolic sine of the number of previous films. Columns 3 and 4 use dummy bins for the previous number of films. The outcome is a dummy for whether the director used a digital or film camera. * p<0.10, ** p<0.05, *** p<0.01

Table A11: Digital Adoption and Movie risk

	(1) digital	(2) digital	(3) digital	(4) digital
Risk Movie z-score (3-yr)	0.032**			
	(0.013)			
Risk Movie z-score (5-yr)		0.027**		
		(0.012)		
Risk Movie z-score (3-yr wins)			0.032**	
			(0.013)	
Risk Movie z-score (5-yr wins)				0.027**
				(0.012)
Observations	1354	1354	1354	1354
Adjusted R^2	0.057	0.056	0.057	0.056

Notes: This table examines whether the ex-ante risk of a movie chosen by a director predicts the director's choice for digital. The outcome is a dummy for whether the director used digital or film. The various measures of risk are estimated calculating the standard deviation of returns among movies that are in the same rating category as the focal movies, either three or five years before the movie year. Given the skewness of the risk measure, we present the result both with and without winsorization (at 1%). The sample used is the one of first-time directors. Robust errors in parenthesis. * p<0.10, ** p<0.05, *** p<0.01

Appendix B: Simple Model

In this Appendix, we discuss more formally the simple model presented in Section 3.2. To be clear, the model does not aim to provide a complete representation of the economic problem but simply to fix ideas about the main mechanisms that could be at play here.

General Setting

The model considers a director of experience level i who can either be experienced (Exp) or inexperienced ($Inex$). They choose to film a movie using technology t which can either be digital (d) or film (f). To make this choice, the director maximizes their lifetime expected utility of the following form:

$$E(U) = E(r_{it}) + \Pr(r_{it} > k_i)\, V_t + c1\{t = d\}$$

Lifetime utility includes three terms. The first term captures the expected return of the next project, which depends on the director's level of experience i, the chosen technology t, and a random component. Specifically, we assume $r_{it} = \mu_{it} + \epsilon_t$ where $\epsilon_t \sim N(0, \sigma_t^2)$. The parameter μ_{it} captures the level of experience with a specific technology. We assume that u_{it} can be either high or low for each technology based on the previous experience with the specific medium. For instance, for directors using film, this parameter can take values μ_{Hf} (high experience with film) or μ_{Lf} (low experience with film) such that $\mu_{Hf} > \mu_{Lf}$. Notice that the expected returns depend on both the level of experience and the technological choice (i.e., the experienced director will have a different payoff if they choose the old versus new technology), while the variance depends solely on the technological choice.

The second term captures the continuation value for a director's career which is the product of the probability that a director will be able to continue directing movies – $\Pr(r_{it} > k_i)$ – and the value of continuing to direct movies conditional on the choice of the technology today V_t. The idea behind the first part is that a director will be able to continue directing movies only if the returns are above a certain level k_i. This threshold k_i captures the level of competition in a specific field: higher k_i implies that the director is less likely to ex-ante continue in their current career of directing movies. Importantly, we assume that the probability of continuing to direct movies is less dependent on current results for experienced directors. For simplicity, we assume that an experienced director can always continue directing films: $\Pr\left(r_{Exp,t} > k_{Exp}\right) = 1$. As a result, we relabel: $k_{Inex} = k$. In general, it is easy to see how the framework could be generalized and incorporated a more nuanced differences in the number of expected movies, without fundamentally changing the implications of the study.

We also want to briefly discuss the intuition behind V_d/V_f. This captures the relative value of being an early adopter in digital versus continuing with the use of film. This will depend on both the actual value of the technology and how much benefit there is from adopting early versus later. In fact, even if digital will be much more valuable in the long run, if a director that uses films in this period can switch to digital in the future at no penalty relative to early adopters, then V_d/V_f will be low.

The third term captures a director-specific preference for using the new technology. We assume this parameter is director specific and is drawn from a uniform distribution defined between 0 and some large value C. The distribution is the same between experienced and inexperienced directors. This is a technical assumption to allow us to estimate the share of directors using the technology.

Consistent with the discussion in the paper, we make two assumptions regarding the nature of the technology. First, there is a difference in learning. The new technology is unknown to everyone: so, whenever any director uses it, regardless of experience level, they will always start from low productivity. However, experienced directors know the old technology and therefore have a "knowledge advantage." This is captured by $\mu_{Hf} > \mu_{Lf}$ and μ_{Hf} is only available to experienced directors using film.

Importantly, we note that this parameter captures the benefit of using a technology, net of any cost. In fact, the benefit of experienced directors using the old technology can come from their higher skill level in using the old technology or from lower learning costs necessary to start a movie. On the other hand, the disincentive of experienced directors in using digital can come from their concerns that they would not be able to be as productive using digital or their incentive to avoid the learning costs (or a combination of the two). In general, we believe that focusing on net benefits is a parsimonious way to present the key economic mechanisms.

Second, there is a difference in risk between the two technologies. As we have shown in the data, we assume $\sigma_d > \sigma_f$. We think this feature is common among new technologies. In Section 2 we provide evidence consistent with the returns for films shot digitally having higher variance than movies shot using film cameras.

Model Discussion

In the next sub-section, we discuss formally the model solution and provide the corresponding derivations. Here, we provide the basic takeaways from this setting.

If we do not consider the role of risk, the relative likelihood of choosing to shoot a movie digitally between experienced and inexperienced directors is determined by the trade-off between the value of the experience with the old technology and the first-mover advantage with the new technology.

On the one hand, the higher the value of experience with the old technology (i.e., $\mu_{Hf} - \mu_{Lf}$), the higher the relative share of inexperienced directors among early adopters. The economic intuition is simple: the more knowledge with the old technology is valuable, the more directors with experience will continue using it. As a result, adoption will be driven by those that have no knowledge of the old technology. For example, if you are in an industry where it is very hard for the inexperienced to catch up to the knowledge level of the experienced, you will tend to see adoption of new technologies driven by newcomers.

On the other hand, if we expect the new technology to be better in the long-run, experienced directors will be more likely to adopt early, all else equal. In our framework, experienced directors are going to direct in the future with certainty, while the inexperienced may be forced to drop out.

As a result, the experienced are more likely to internalize the long-run benefit that may arise from adopting the new technology early.

Because of this fundamental trade-off in adoption, the relationship between experience and adoption is ex-ante ambiguous. This implication is only reinforced when we consider the role of risk. The fact that the inexperienced need to prove themselves in the current project, since they may not be able to continue producing, implies that risk is an important variable when deciding which technology to use. However, the direction of the impact of risk depends on the level of competition in the market, which is measured by the parameter k in the setting discussed before. When the level of competition is low (i.e., most inexperienced directors will be able to become experienced), then an inexperienced director will generally be risk-averse and avoid adopting the new technology: in this context, the idea is that reaching the right-tail will have limited benefits in this setting, since most people will be promoted anyway, but a very negative outcome could be instrumental in derailing a career. As a result, when competition is low, people tend to behave as if they are risk-averse. In contrast, when competition is high, new directors will tend to prefer the riskier technology. In this case, the benefits of the right-tail are high, and workers try to take the risk. We provide a simple proof of this mechanism in the next section.

Model Solution

For those interested, we now discuss more formally the solutions for the framework. In general, our framework is extremely simple. As discussed before, the utility of an inexperienced director choosing technology t is:

$$U_{Inex} = E(r_{Inex,t}) + \Pr(r_{Inex,t} > k)\, V_t + c1\{t = d\}$$

For an experienced director, their expected utility is:

$$U_{Exp} = E(r_{Exp,t}) + V_t + c1\{t = d\}$$

If you are an experienced director, then you would choose digital if:

$$E(r_{Exp,d}) + V_d + c > E(r_{Exp,f}) + V_f$$

$$\Rightarrow c > (\mu_{Hf} - \mu_{Ld}) + (V_f - V_d)$$

Given the uniform distribution assumption for c, the share of directors choosing digital is:

$$ExpShare = 1 - \frac{(\mu_{Hf} - \mu_{Ld}) + (V_f - V_d)}{C}$$

When a director is inexperienced, they choose digital if:

$$E(r_{Inex,d}) + \Pr(r_{Inex,d} > k)\, V_d + c > E(r_{Inex,f}) + \Pr(r_{Inex,f} > k)\, V_f$$

Labelling $\Pr(r_{it} > k) = \Phi_t$ and rearranging yields:

$$c > (\mu_{Lf} - \mu_{Ld}) + (\Phi_f V_f - \Phi_d V_d)$$

This implies that the inexperienced share is:

$$InexShare = 1 - \frac{(\mu_{Lf} - \mu_{Ld}) + (\Phi_f V_f - \Phi_d V_d)}{C}$$

We can now calculate when inexperienced directors are more likely to adopt digital technology than experienced directors. This is defined by the expression:

$$1 - \frac{(\mu_{Lf} - \mu_{Ld}) + (\Phi_f V_f - \Phi_d V_d)}{C} > 1 - \frac{(\mu_{Hf} - \mu_{Ld}) + (V_f - V_d)}{C}$$

$$\Rightarrow (\mu_{Hf} - \mu_{Ld}) + (V_f - V_d) > (\mu_{Lf} - \mu_{Ld}) + (\Phi_f V_f - \Phi_d V_d)$$

$$\Rightarrow (\mu_{Hf} - \mu_{Lf}) > (1 - \Phi_d)V_d - (1 - \Phi_f)V_f$$

From this formulation, it is easy to observe the basic trade-off between knowledge benefits $(\mu_{Hf} - \mu_{Lf})$ and first-mover advantage V_d/V_f, as discussed before.

The statement about risk is instead a bit more demanding. To examine how risk affects the relative probability that inexperienced versus experienced dominates among early adopters, we can conduct the following thought experiment. We can start from a condition in which the two technologies have the same level of risk, and then study how a marginal increase in risk (i.e. increasing σ_d^2) affects the condition above. Before doing this, we need to observe that:

$$\Phi_t = \Pr(r_{it} > k) = \Pr(\epsilon_t > k - \mu_{it}) = 1 - CDF_t(k - \mu_{it}) =$$

$$= 1 - \left[.5\left(1 + erf\left(\frac{k - \mu_{it}}{.5\sigma_t^2}\right)\right)\right]$$

This implies that the condition above can be rewritten as:

$$(\mu_{Hf} - \mu_{Lf}) > .5\left(1 + erf\left(\frac{k - \mu_{it}}{.5\sigma_d^2}\right)\right)V_d - .5\left(1 + erf\left(\frac{k - \mu_{it}}{.5\sigma_f^2}\right)\right)V_f = \Delta$$

Where we define Δ for convenience. Our problem then is essentially to sign $\frac{\delta\Delta}{\delta\sigma_d^2}$. We can start by writing:

$$\frac{\delta\Delta}{\delta\sigma_d^2} = .5V_d \frac{\delta erf\left(\frac{k - \mu_{Ld}}{.5\sigma_d^2}\right)}{\delta\sigma_d^2}$$

Which can be rewritten as:[1]

[1] Since, $\frac{\delta \text{erf}(x)}{\delta x} = \frac{2}{\sqrt{\pi}} e^{-x^2}$.

$$\frac{\delta\Delta}{\delta\sigma_d^2} = -.5V_d \frac{2}{\sqrt{\pi}} e^{-\left(\frac{k-\mu_{it}}{.5\sigma_d^2}\right)^2} \left(\frac{k-\mu_{Ld}}{.5\sigma_d^2}\right)$$

Now, the sign of this derivative depends on $k - \mu_{Ld}$. Notice that the sign of $k - \mu_{Ld}$ can be interpreted as the proxy for the level of competition in the market. When $k - \mu_{Ld} > 0$, this means that the majority of managers starting will fail to keep working in the future. If $k - \mu_{it} > 0$, then the sign is negative. This implies that if the variance increases, Δ decreases, and therefore it is more likely that we will have the inexperienced adopt. If $k - \mu_{it} < 0$, then the derivative is positive, and the intuition is the opposite.

This result is in line with the economic intuition: when the level of competition for the job is sufficiently high, taking a riskier option is optimal. On the other hand, when the baseline assumption is that the manager will be able to stay in the market, higher risk is bad and should be avoided.