# Technology Adoption and Career Concerns: Evidence from the Adoption of Digital Technology in Motion Pictures

By

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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.

**JEL Codes**: D22, L20, M19.

**Key Words**: Technology Adoption, Career Concerns, Digital Transition, Film Directors.

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## 1 Introduction

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 depends 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., 2019), coordination (e.g., Caoui, 2022, Crouzet et al., 2022, Feigenbaum and Gross, 2022), or financial development (e.g., Comin and Nanda, 2019; Bircan and De Haas, 2019).

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. Our analysis also suggests that the career concerns which characterize the industry—particularly the drive to stand out or the willingness to embrace riskier technologies—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.

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, a new technology is generally characterized by a higher-level of risk,[2] which can either come from the novelty of the technology or from uncertainty about its commercial applications. Third, a new technology is generally not introduced at its full potential, which may imply that early adopters benefit from joining at the early stages of development. However, others may prefer to wait until the technology is fully developed.

[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).

In this context, we argue that it is ex-ante unclear how career considerations affect the decision to adopt a new technology. Experienced managers already have some pre-existing knowledge about the old technology, and therefore may not want to try the new one. Newcomers on the other hand, have no experience with either technology and may need to put equal effort into learning either of the two technologies. However, typical career concern models (e.g., Holmstrom, 1999) and 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 a 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, may take greater risks.[3] In other words, theory provides ambiguous predictions regarding the role of career concerns in technology adoption decisions.[4]

The literature acknowledges 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 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.[5] 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 (See John et al, 2017, Han and Ravid, 2023).

While available, digital shooting was very rarely used for movies produced 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

[3] 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.

[4] 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.

[5] 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.

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. Our core focus will be on the period before this shift, when (a) we see the first large increase in the use of digital technology in features films; (b) the weaker economic benefits of adopting digital technology implied that directors had greater autonomy to decide which technology they should use for shooting.

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.

We then show that our findings are likely to be related to career concerns. To start, we show that the "first timers" effect is mostly driven by the period between 2002 and 2006, which is exactly when the first wave of adoption happened, and the level of uncertainty about the technology was high. This evidence is consistent with a career concerns model, and exactly the opposite of what most alternative explanations would predict. For instance, if our results were due to some financial benefits to using digital, we should have found that the gap in the rate of adoption between experienced and inexperienced directors would have increased as the use of digital technology became more widespread and economic incentives in favor of this option became stronger (i.e., post 2006). [6] However, our results point exactly in the opposite direction.

We can also more directly rule out the leading alternative mechanisms that may explain our results. First, we show that our findings cannot be explained by differences in bargaining power between the director and the production company. 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.[7] We can replicate our findings when we use this sub-sample as the control group. Third, we show that the results are not driven by the early exposure to digital technologies but 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.

[6] As we discuss later, one alternative explanation is that inexperienced directors are more sensitive to the financial cost of using digital or are more likely to be pressured by production companies to use digital. Both stories would predict stronger effects as digital becomes cheaper over time and the financial benefits of using digital increases after theater adopt digital projection. Section 4 explains this argument more in details and also provide other results that are inconsistent with these explanations.

[7] 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.

We do find that technical expertise favors adoption. However, the technical expertise mechanism operates independently from the career concerns of the director as 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., 2022; Crouzet et al, 2024; Feigenbaum and Gross, 2022; Gupta et., 2019; 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 technology adoption in industries. 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.[8]

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). Papers in this area include Caoui (2022), who studies the adoption of digital projection for movie theaters in France. That paper 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) shows the effect of the diffusion of digital exhibition in South Korea on the choice of films available to consumers. Nagaraj and Ranganathan (2022) examine 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.[9]

This paper also contributes to the literature in finance that studies the effects of career concerns on managers' behavior. Focusing largely on the investment industry, several papers show that

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[8] Our analysis complements work in innovation focusing in 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 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., (2024), 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., (2024) is interested on how consumers' heterogeneity can be internalized by otherwise homogenous entrepreneurs.

[9] 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 (2023) discuss the market for film directors; Chisholm and Norman (2006) study the optimal exit choice in a multi-product market; Gil (2015) examines 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.

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 a 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 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]

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

In this section, we first describe the introduction of digital cameras and the main factors affecting this process. 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 how professional directors think about digital versus film technology.[12] In the second part of this section, we describe in detail the data used in the empirical portion of the paper.

### 2.1 Digital Movies

Movies have been shot on film since the beginning of the motion pictures 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)

[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. Our discussion in Section 5 will try to explain the motivation behind this result.

[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).

[12] 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 hundred directors who had never directed a feature). The vast majority of respondents used digital technology at some point.

with Kathleen Turner and Sting. However, the movie had to be converted back to film to be shown in theaters.

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), but 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 limited.

In 1999, George Lucas and others introduced the first digital projectors. The first digital 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. 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 that year 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. 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. 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, from an economic standpoint, digital became a clearly superior option only after 2007, when the ability to distribute digitally significantly improved the payoff of digital movies. 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".[13] Indeed, even Tarantino's most recent film, in 2019 was shot on film (and converted to digital for distribution). 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

[13] https://www.digitalspy.com/movies/a441960/quentin-tarantino-i-cant-stand-digital-filmmaking-its-tv-in-public/

making some money out of it." Other directors supporting film include the most 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 shot on film.

In 2023 the movie "Sharper" was shot on film and this exchange between the movie's director Benjamin Caron and interviewer Kerry Nolan is instructive 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."[14] Some directors in our survey also expressed similar concerns. For example, one stated they were "concerned that digital would not look enough like film".

At the other end of the spectrum, some well-known and 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 the 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 film 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

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

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).[15] 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 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 as digital given that the director chose to adopt digital film technology for at least part of the filming process.

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 change during the 2000s, and the share of digital films increased steadily, reaching approximately 21% in 2008. As discussed before, 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. 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.[16] The trend in adoption of digital cameras he documents is nearly identical to our categorization.

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, the IMDb page provides detailed career information listing the complete history of films the individual directed,

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[15] 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

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

as well as a range of other roles they may have had in film production and in television (i.e., credits). This career information is useful to control for other potential mechanisms affecting the decision to adopt digital technology. For example, having previous experience in technical roles (e.g., as a cinematographer, DP) might lower the cost of adopting the new technology as a director. The resulting dataset is at the film-director level containing all films with U.S. box office revenue of at least $10,000 from 1975 to 2018.[17]

## 3 A Conceptual Framework

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. Second, we develop explicit hypotheses about how such career concerns can affect technology adoption given the specific characteristics of the industry.

### 3.1 Career Concerns and Technology Adoption

The adoption of digital filming can provide new insights into how a manager's career concerns affect the incentive to adopt a new technology. Film directors are responsible for both the creative and the business aspects of the film. They provide the vision but also have to bring the project to a conclusion on time and within budget. In our context, they can be thought as project managers who need to decide which technology to adopt in order to maximize their career prospects in an uncertain labor environment. [18]

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). 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, previous studies 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

[17] 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 really awful films (high budget, but total failures) so that we include only bad films that at least had some audience. There are typically 300-400 such movies released every year (see Han and Ravid, 2023).

[18] People who are not familiar with the motion pictures industry may think that producers are in charge of film projects. However, this is generally not the case, although as always, there is some bargaining in every financial decision. As discussed in Han and Ravid (2023), the term (or credit in the movie for) producer means many things in the business. The most important credit is that of "Producer" and it is generally accorded to the person(s) who initiates a project, sells it to a studio, and/or develops and shepherds it through the system until it is produced and released. The Executive Producer credit is usually reserved for a variety of people associated at one time or another with a project, in one form or another. 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.

may be different along several dimensions.[19] First, a new technology is a product or process for which no one has extensive experience. This does not necessarily imply that experience with the old technology is not relevant when operating the new equipment, but some significant frictions in the transfer of knowledge should be expected.

Second, new technologies are usually not introduced at 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, this is likely to increase (decrease) over time relative to the old technology. One implication of this feature is that adopting early may be valuable, at least in some cases. Early adopters – by learning how to use the new technology – may be able to reap some of the benefits of these improvements in the long run. This feature will depend on the specific nature of the technology, and the extent to which this is likely to generate a "first-mover advantage" in the market. On the other hand, waiting may avail the manager with more user-friendly technology while allowing her to use the old technology to its full potential.

Third, while early on a new technology is not necessarily "better" than an old one, it is generally characterized by a higher level of risk. In other words, new technologies present both higher upsides and lower downsides. Risk in our context can come from the nature of the technology itself or from uncertainty about market demand. For instance, in our specific application, there were concerns about whether viewers would like the films shot using digital technology.

Therefore, the problem of technology adoption is different from a core business decision. In this context, we think that the digital transition in movies fits this conceptual framework well and can represent a fruitful area of analysis. First, 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".

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. One of the directors in the survey 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 and cost much less than film." On the other hand, one director mentioned "[digital] was also worth learning as many believed rightly it would be the future."

Similar to other forms of creative activity (Åstebro, 2003), movie production is always a risky activity. However, recording a movie with a digital camera was perceived as a higher-risk

[19] We provide this characterization to help the reader thinking through our conceptual context and provide a benchmark to differentiate the adoption of a digital technology from other investment. Clearly, we do not see this characterization to be universal. Furthermore, we do not think that each new technology will be characterized by all three features with the same strength.

endeavor, at least in the relevant period. Many players in the industry were concerned that audiences would perceive digital films to be of lower quality. For example, a director in our survey stated that “historically things shot digitally looked fake to me.” Other directors mentioned risk more directly. One director in our sample called digital “Cheaper, faster but risky” and another mentioned “uncertain outcome.” A director who apparently had worked through the transition, characterized directors who decided to stay on film saying, “they took less risk” whereas the others were willing to “take that leap”.

Directly measuring ex-ante risk is intrinsically difficult. However, we can provide evidence consistent with the idea that digital cinematography was riskier by checking whether risk for digital movies was higher ex-post. For that purpose, we calculate returns on each film in our sample, measured as revenues divided by the production budget. Returns data indeed confirm this idea that digital movies are characterized by relatively higher risk. In Table 1, we classify movies by their family friendliness MPAA 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 provide different returns on average and unlike genres which can overlap, they partition the set of films produced (Ravid, 1999, Basuroy and Ravid, 2004). Other work also suggests that MPAA ratings classes have differential risk characteristics (e.g., Palia et al. 2008, Basuroy and Ravid, 2004). We then compare the standard deviation of returns between these categories for movies produced between 1998-2009, as a proxy of the ex-post realized risk for each category.[20]

Across essentially all rating groups digital movies show systematically higher risk compared to movies recorded on films. For instance, PG movies recorded on films have a standard deviation of 8.93, while the SD for digital is 48.9. Given the highly skewed nature of movies’ returns, we also show that this regularity does not depend on the tail 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.[21] Furthermore, this evidence does not simply reflect compositional differences in the pool of talents between movies shot digitally versus on film.[22]

Lastly, 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 bottom 10% in terms of returns during our period. Our analysis reveals 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.

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

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

[22] In Table A9, we reproduce Table 1 now splitting based on the experience of the director (as defined by the number of previously directed films), and we find that the highest variance still holds across experience levels, therefore confirming that the result in Table 1 does not simply reflect differences in the talent pool.

Altogether, while there may be other characteristics of new technologies we may not 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 a new technology from other corporate actions.

### 3.2 Hypothesis Development

Having introduced the key features of our technology adoption setting, we now discuss how career concerns may affect the likelihood of technology adoption. In a standard career concern model, managers differ based on their level of reputation or experience in the industry, such that more reputable managers face a higher probability of continuing their career irrespective of the outcome of the next project. However, low reputation (or low experience) managers need to prove themselves in the short run to signal their underlying quality, and therefore grow in their career.[23] In this setting, the relationship between career concerns and adoption is non-trivial.

First, independent of their technology choice, experienced directors are generally more likely to continue in the profession compared to inexperienced directors (continuation advantage). In other words, the ex-ante likelihood to direct a new movie after the next one is higher for experienced directors. Empirically, this idea is consistent with the evidence in John et al. (2017) and Han and Ravid (2023). Conceptually, this hypothesis 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 line of thinking would induce us to believe that more experienced managers may lead the leap into the unknown. Because of their higher likelihood of being active in the future, experienced directors are going to internalize more the long-term benefits of adopting the new technology early.[24] The strength of this mechanism depends on the expected quality of the new technology over the long-run, but also on the expected first-mover advantage of adopting the new technology early.[25]

On the other hand, managers at different points of their careers will also differ in their relative level of familiarity with the two technologies (knowledge premium). By definition, experienced directors have already used the old technology and therefore are relatively more knowledgeable

[23] In this section, we use reputation and experience largely interchangeably. In the next section, we discuss how we plan to measure this dimension in the data, and therefore provide a more detailed definition of this property.

[24] The same prediction may also be generated by the presence of a "Matthew effect" for technology adoption, where experienced directors are rewarded more for making the same leap into the unknown (Azoulay et al., 2014).

[25] To be precise, what is relevant in this case is the extent to which the current decision to use digital will be beneficial relative to someone that adopted later. If a director adopting later will be at no disadvantage relative to someone adopting early, the incentive coming from this mechanism could still be low. We come back to this point in Section 5.

about it. In contrast, first-time directors will not have any pre-existing advantage in either technology. In other words, experienced directors will have a comparative advantage in the old technology at any point in time, and thus may decide to switch later, everything else equal. Furthermore, the strength of this mechanism will depend on the size of the "knowledge premium.[26]

Therefore, the basic trade-off in adoption is that experienced and reputable directors – who have established expertise in the old technology – are generally biased towards adopting later. However, if the benefits of early adoption are sufficiently large, this result may change. In this case, experienced directors – who are more likely to internalize the future benefits – may lead the technology transition.

Differences in risk between the new and the old technology can also play a role in affecting decisions. In fact, a director's level of experience may affect her preference for risk. The direction of this effect is ex-ante unclear. Consider a case in which the labor market is not very competitive: managers expect to continue their career if their next project is not extremely bad. In this case, new managers will – all else equal – prefer to use the old technology. In fact, this type of labor market incentivizes managers to play it safe, and at the margin avoid undertaking riskier options. Importantly, because experienced managers are more likely to continue operating irrespective of the outcome of the next project, this incentive will get weaker as experience increases. The risk avoidance mechanism is conceptually similar to the traditional "herding behavior," that previous research (e.g., Chevalier and Ellison, 1999a; Hong, Kubik, and Solomon, 2000; Lamont, 2002) proposed as an important process explaining how career concerns affect managers' behavior in the financial industry.

However, in some markets managers are allowed to continue working only if their project is extremely successful. This is akin to a very competitive labor market, where only a few exceptional candidates are rewarded. In this case, managers may be incentivized to be risk-takers to maximize the probability of over-performance. As before, this mechanism will affect inexperienced managers, whose reputation is not yet fully established.[27]

Thus, differences in risk play an ambiguous role, potentially incentivizing the adoption of new technology by newcomers in very competitive markets but reducing adoption by newcomers in more stable environments.[28] Such distinction may account for the observation that in risky

[26] Notice that this difference could also be negative: for instance, sometimes a new technology could be so much better that – despite a lack of experience with it – a user can be more productive than with the old technology.

[27] 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.

[28] A simple numerical example based on a binomial distribution may help build intuition. Consider two technologies: a risky technology has a 70% probability of generating zero revenue and a 30% probability of generating some positive value M; and a safe option that has equal probabilities of receiving either zero revenues or 0.6M. The two technologies have the same expected revenue, but the riskier technology has a higher variance. Assume that experience dictates the minimum level of revenue that are required to continue in the profession. If experience managers only have to clear a low bar (e.g., 0.2M), then the optimal strategy for the director is to use the safe technology, since this gives her a 50% probability of continuing, as opposed to a 30% probability if the risker technology is adopted. However, if the

professions such as directing – discussed further below – which has a dropout rate of well north of 50% young directors may decide to take the leap into a new and risky technology whereas in a relatively safe profession such as analysts (Hong et al., 2000) where the overall probability of termination is 15% (IBID table 2- up to 22% for first year analysts- or similarly in Chevalier and Ellison, 1999 figure 1) herding may be optimal for newcomers..

Altogether, the theory provides an ambiguous prediction about how career concerns should affect technology adoption. Different mechanisms should be at play simultaneously and their impact on technology adoption decisions can be mixed. In Section 5, we come back to the framework presented here to discuss the external validity of our results, outside the specific empirical context studied.

## 4 Adoption of Digital Filming and Director Experience

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 three sections provide some robustness checks and discuss potential mechanisms.

### 4.1 Empirical Setting – Movie Directors' Careers

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 the 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, 2023).

Second, in a typical organization, the adoption of a new technology may reflect both the incentives of a local manager and the authority of the headquarters. Our context is much cleaner in 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.

Third, directors' careers are risky and start at a late age, hence career concerns are of paramount importance. Han and Ravid (2023) 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 (2023) 84% of male directors who entered the profession between

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threshold is high (e.g., 0.8M), then it is optimal for a manager to take the riskier strategy since with the safe strategy the probability of staying in the profession is zero.

1995 and 2015 and 90% of the female directors in the same cohort made two films or fewer before dropping out. Given that the average budget in that sample was over $40 million in 1998 dollars it is not surprising that failure or mild success was not sufficient to allow directors to be hired again and control projects worth tens of millions of dollars.[29] 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.

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 test whether the ex-ante experience of a director increases her incentive to use digital versus films. We estimate an equation of this form:

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

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 camera, and zero otherwise, $\alpha_t$ 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.[30]

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 actual experience of the individual as a director, measured by the count of feature films previously directed. 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 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.

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. 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.

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[29] The situation is different for experienced directors – both papers (Han and Ravid, 2023 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.

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

There are four 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).[31] 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). However, we will show consistent results with the full sample or using a non-parametric approach. Finally, our main analyses include movies between 1997 and 2009, but we examine different samples in later analyses. [32]

**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. 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).[33] In Table 3, we replicate the same analysis defining experience in two alternative ways. First, rather than looking at the simple count of past movies, we proxy this

[31] 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. Recently, it is generally used more frequently than the log(x+1). 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.

[32] 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 small number of movies for which we cannot identify whether they were shot on digital or film cameras because of a lack of data.

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

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.[34] 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.

In addition to confirming that less experience is generally associated with higher adoption probability, 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. Notice that this result is consistent with our interpretation of the relationship between career concerns and technology adoption.

Lastly, we also show that this result – directors with weaker reputation and experience 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 A1, 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 in film rating and genre. While we recognize the difficulty of cleanly separating these different dimensions, in Section 4.4 and 4.5 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 A2 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 A3 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, very few G-rated films are produced each year.

Third, in Table A4, we show consistent results when controlling for past adoption of digital. While essentially no films had been shot digitally before our sample period, as we move past 2000 our sample contains directors who might have already filmed a movie digitally but are not considering the technology to use for a follow-up movie. To adjust for this dynamic dimension, we also include

[34] 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).

past adoption decision by the director.[35] The inclusion of this control does not generally alter our conclusions: if anything, we find a marginal increase in the size of the coefficients.

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 as a control variable in our analysis. In Table A5, we find very similar effects relative to the baseline.[36] Other prior experience variable seems 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 A6, 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.

Our interpretation of the findings is supported by examining the timing of our effects. We divide the sample period in 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, when the technology started becoming mainstream. 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.[37] After 2006, the effect is smaller in size and not significantly different from zero. This evidence is consistent with our career concerns interpretation. 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 shows that career considerations were important for the adoption of digital filming. 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

[35] To be clear, 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.
[36] 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.
[37] 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.

experienced. We also find that the effect of experience on technology adoption is most pronounced in the period where risk and uncertainty about the potential of the new technology were higher, which should give rise to career concerns. The effect disappears as digital technology becomes more widespread.

### 4.4 Experience and Technology Expertise

Before we discuss the 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 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 previous industry experience, then those who had worked in some technical capacities should have been more adept with new technology.[38]

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 one 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 technical expertise is not explaining our findings 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. To be clear, this mechanism is not inconsistent with our conceptual framework: as we discussed in Section 3, experienced managers are - by definition - more knowledgeable about the old technology, and therefore they may be more conservative in their technology choices. However, it seems helpful to examine to what extent our effect may reflect exposure to training.

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. Our argument is that it is experience rather than age that matters. 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 that are forty years or older in 2000.[39] This sample is much smaller than the main one, but we still find results that are consistent

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[38] 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.

[39] 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

with our previous results. These findings suggest that the preferences for digital production are not because of education or technical expertise. While we recognize that separating age and experience is challenging both empirically and conceptually, it seems that the adoption decision reflects experience more than just older age. This strengthens our career concerns interpretation.

**4.5 Alternative explanations**

We now consider some alternative explanations for our results. One interpretation may 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 inexperienced director. 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 is thus plausible that more experienced directors may have more freedom to choose their teams and technology. However, the implication of this statement does not align with the timing of the effects discussed earlier.

As we discussed before, 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 our results 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 reflect bargaining between the director and the producers, we should expect that other proxies for the bargaining power of the director would (negatively) predict adoption, over our measure of experience. 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.[40]

We present these results in Table A7. To proxy a first-time director's outside options, we use both the number of total credits (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 measure aims to capture the relatively common case of a famous actor starting to direct later in her career. This is exactly a situation where a person would have 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 as actors or writers. We find that both measures of bargaining

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IMDb. To supplement this information, we manually searched directors on Wikipedia and identify the birth year for almost 60% of them.

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

power do not predict differential adoption, and this is true both when using a continuous version (odd columns) or a dummy variable capturing those directors in the top quartile of this measure.[41]

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 A1). 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 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.[42]

Despite these structural constraints, we try to address this issue in several ways. Conceptually, as discussed before, a significant economic advantage of filming a movie digitally is in the distribution process. However, until roughly the end of the first decade of the 21st century, most movie theaters were not equipped with digital projectors, and therefore most movies were distributed as film copies. This implies that the incentive to go digital was lower in the early 2000s than after 2006. Therefore, if financial incentives drive our results, we should see that our effects become stronger over time, as the economic benefit of digital increases and the cost of digital equipment declines. However, as discussed earlier, our effects are less relevant after 2006 (Table 4). Also, the cost of film or equipment in general is not paramount for the typical production considered in this study.

Empirically, we can conduct two useful exercises. First, despite the limitations discussed above, we can ideally check 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 confirm that despite the significantly smaller sample size, our findings remain largely unchanged. This suggests that our estimated effect of experience 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 more 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,

[41] We thank Yakov Amihud for suggesting this test.
[42] As we were able to check manually, budget is generally always available for larger productions, while it may be missing for smaller projects.

also interacted with year dummies.[43] The results are presented in Table A8: 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 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.[44]

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, it 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 8, we compare movies that were shot digitally to other movies that were not shot digitally but that undertook a digital intermediate step during production.[45] 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.

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 seems to hold 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 relative incentive to adopt a new technology. We find that during the first adoption wave of digital cinematography in the motion picture industry the utilization of this new technology was largely

[43] In particular, the ten groups are created as a combination of night 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.

[45] 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.

driven by inexperienced directors. This suggests that managers in their early career may play a particularly important role in the propagation of new technologies in the workplace.

Before concluding, we want to briefly discuss how our results align with the framework presented in Section 3. The first observation is that - given our knowledge of directors' career - it is not surprising that inexperienced directors played a leading role in the adoption of digital filming. The two main forces that might have led to a different outcome are a strong incentive to avoid risk among newcomers (similar to herding observed in other settings) and a large "continuation advantage" for experienced directors. In general, we believe these scenarios are both unlikely in our case.

As discussed in John et al. (2017) and Han and Ravid (2023) and confirmed in our data, the market for feature directors is extremely competitive, and early career directors can continue directing feature films only if they are extremely successful. 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.

While harder to exclude ex-ante, we also believe that the benefits of early adoption in our context were probably limited. Even if digital technology became ex-post the norm in the US movie industry, it is not clear that those that first movers gained a significant advantage relative to those who postponed adoption. Indeed, the movie industry is characterized by large and infrequent projects, and therefore a director who does not adopt immediately is likely to be able to switch to digital later, if the value of switching is high. This explains why more experienced directors who, by definition, have a comparative advantage in the older technology (film) delayed adoption.

This discussion is important because it can also help us in thinking 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. 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. In this sense, public administrations may represent an interesting case to study, since 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" or "herd" and avoid taking any initiative that would generate downside risk, irrespective of the upside that can be captured.

Another important aspect is the long-run benefit of early-adoption. As we discussed above, this benefit depends on both the actual value of the technologies over the long-run and the benefit that accrues to early adopters. All else equal, if adopting early will generate strong reputational benefits, we should expect experienced agents to be more active in experimenting with the new technology. The importance of these reputational benefits will depend on the specific nature of the industry.

In our view, there are three takeaways from this discussion. First, regardless of the specific mechanism, our result suggests that the type of career progression and the mix of early career and more experienced employees may critically affect technology adoption in industries. 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 our result is likely to be relevant for 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 share many similarities with the film industry, and therefore our results may have a more direct application to those contexts.

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. Other industries and technologies may differ across dimensions in our conceptual framework – such as the threshold for being able to continue, the long-run value in adopting the new technology, or the inherent riskiness in the new technology – and this may lead to different results than found here. In this context, our analysis represents one of the first attempts to provide a systematic empirical and conceptual framework to guide researchers studying these other areas.

**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. Three features appear to be particularly salient: the degree to which experience with the old technology accumulated by more experienced managers may generate sizable benefits; the long-term value of switching to the new technology early; and the extent to which high levels of competition may incentivize early-career managers to take riskier options, therefore favoring the adoption of a new technology.

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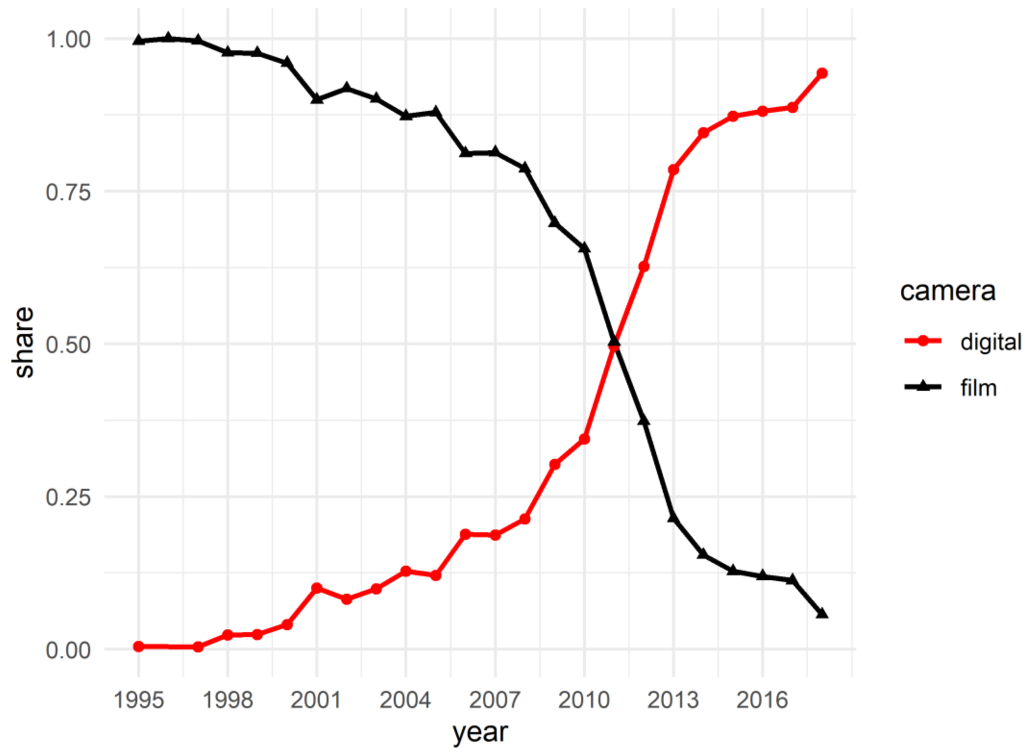
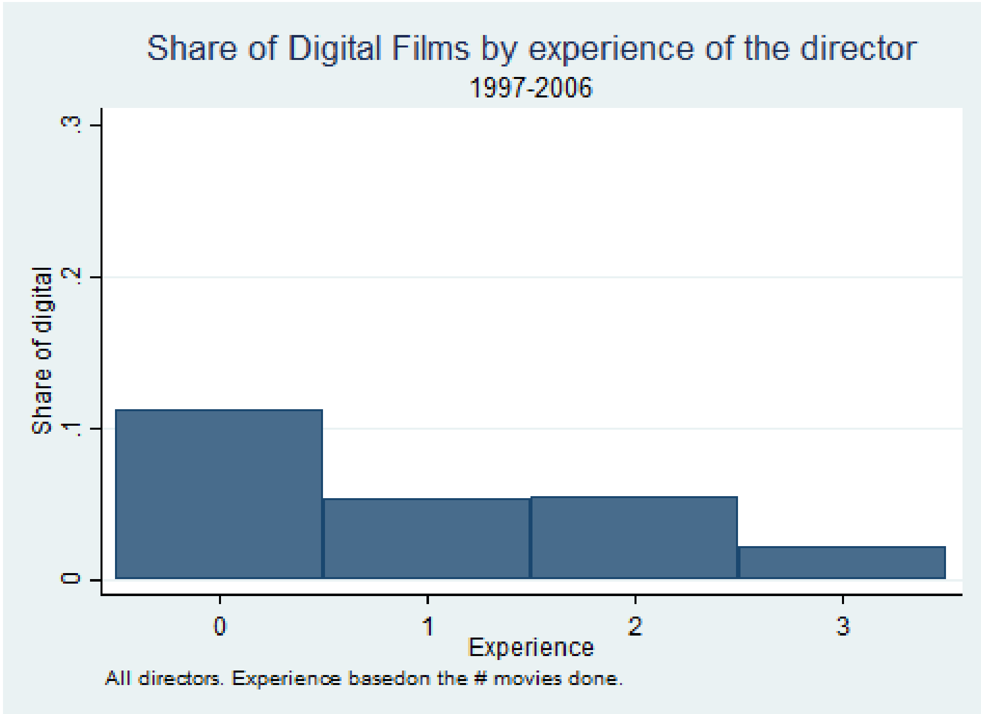
# Figures

**Figure 1**




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

**Figure 2**




Notes: this figure reports the probability that a director will choose a digital camera conditional on different levels of previous experience. 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.

# 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 | 8.93 | 9.83 | 3.06 | 3.41 |
| | SD Digital | 48.96 | 49.97 | 8.12 | 9.57 |
| PG13 | SD Film | 4.76 | 5.14 | 2.92 | 3.21 |
| | SD Digital | 4.84 | 4.85 | 4.52 | 4.84 |
| R | SD Film | 122.84 | 9.49 | 3.75 | 3.98 |
| | SD Digital | 1048.77 | 1066.57 | 5.56 | 6.11 |
| Unrated | SD Film | 6.53 | 6.91 | 3.97 | 4.56 |
| | SD Digital | 9.51 | 9.76 | 6.02 | 6.64 |

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) | (2) | (3) | (4) |
|---|---|---|---|---|
| | digital | digital | digital | digital |
| # Previous films (IHS) | -0.017*** | -0.017*** | -0.012** | -0.011** |
| | (0.005) | (0.005) | (0.005) | (0.005) |
| Genre F.E. | No | Yes | No | Yes |
| Rating F.E. | No | No | Yes | Yes |
| Observations | 3776 | 3776 | 3776 | 3776 |
| Adjusted $R^2$ | 0.057 | 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)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital |
|---|---|---|---|---|
| Previous Movie Revenue (IHS) | -0.009*** | -0.005** | | |
| | (0.002) | (0.002) | | |
| Only One Prev. Movie | | | -0.039*** | -0.033** |
| | | | (0.014) | (0.014) |
| Only two previous movies | | | -0.068*** | -0.058*** |
| | | | (0.016) | (0.016) |
| >2 Prev. Movies | | | -0.043*** | -0.030** |
| | | | (0.012) | (0.013) |
| Genre F.E. | No | Yes | No | Yes |
| Rating F.E. | No | Yes | No | Yes |
| Observations | 3776 | 3776 | 3776 | 3776 |
| Adjusted $R^2$ | 0.059 | 0.073 | 0.060 | 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)<br>digital | (2)<br>digital |
|---|---|---|
| Prev. Films X 1997-2001 | -0.005 | 0.001 |
| | (0.005) | (0.005) |
| Prev. Films X 2002-2006 | -0.035*** | -0.028*** |
| | (0.008) | (0.008) |
| Prev. Films X 2006-2010 | -0.002 | 0.000 |
| | (0.014) | (0.014) |
| Genre F.E. | No | Yes |
| Rating F.E. | No | Yes |
| Observations | 3776 | 3776 |
| Adjusted $R^2$ | 0.059 | 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)<br>digital | (2)<br>digital | (3)<br>digital |
|---|---|---|---|
| # Previous films (IHS) | -0.015*** | | -0.016*** |
| | (0.005) | | (0.006) |
| Only One Prev. Movie | | -0.032** | |
| | | (0.014) | |
| Only two previous movies | | -0.059*** | |
| | | (0.016) | |
| >2 Prev. Movies | | -0.037*** | |
| | | (0.013) | |
| Technical Expertise=1 | 0.077*** | 0.076*** | 0.072*** |
| | (0.013) | (0.013) | (0.021) |
| Technical Expertise=1 # # Previous films (IHS) | | | 0.004 |
| | | | (0.013) |
| Genre F.E. | Yes | Yes | Yes |
| Rating F.E. | Yes | Yes | Yes |
| Observations | 3776 | 3776 | 3776 |
| Adjusted $R^2$ | 0.083 | 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)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital | (5)<br>digital | (6)<br>digital |
|---|---|---|---|---|---|---|
| # Previous films (IHS) | -0.016** | -0.014** | | | | |
| | (0.007) | (0.007) | | | | |
| Previous Movie Revenue (IHS) | | | -0.006** | -0.003 | | |
| | | | (0.003) | (0.003) | | |
| Only One Prev. Movie | | | | | -0.045** | -0.042** |
| | | | | | (0.021) | (0.021) |
| Only two previous movies | | | | | -0.041* | -0.035 |
| | | | | | (0.024) | (0.024) |
| >2 Prev. Movies | | | | | -0.049*** | -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 | 1668 | 1668 | 1668 | 1668 | 1668 | 1668 |
| 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 4 and 5 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) | -0.018*** | -0.013** | | | | |
| | (0.006) | (0.006) | | | | |
| Previous Movie Revenue (IHS) | | | -0.011*** | -0.007*** | | |
| | | | (0.002) | (0.003) | | |
| One Prev. Movie | | | | | -0.036** | -0.029** |
| | | | | | (0.015) | (0.015) |
| Two Prev. movies | | | | | -0.061*** | -0.050*** |
| | | | | | (0.017) | (0.017) |
| >2 Prev. Movies | | | | | -0.044*** | -0.034** |
| | | | | | (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 | 2981 | 2981 | 2981 | 2981 | 2981 | 2981 |
| Adjusted $R^2$ | 0.065 | 0.081 | 0.066 | 0.080 | 0.069 | 0.084 |

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 4 and 5 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: 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 | | | -0.140*** | -0.111*** |
| | | | (0.034) | (0.034) |
| Only two previous movies | | | -0.200*** | -0.164*** |
| | | | (0.036) | (0.036) |
| >2 Prev. Movies | | | -0.167*** | -0.116*** |
| | | | (0.029) | (0.030) |
| Genre F.E. | No | Yes | No | Yes |
| Rating F.E. | No | Yes | No | Yes |
| Observations | 1436 | 1436 | 1436 | 1436 |
| Adjusted $R^2$ | 0.063 | 0.109 | 0.072 | 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

# Appendix A: Additional Tables

Table A1: 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*** | -0.011** | | | | |
| | (0.005) | (0.005) | | | | |
| Budget (IHS) | | | -0.041*** | -0.047*** | | |
| | | | (0.005) | (0.006) | | |
| Age (IHS) | | | | | -0.077*** | -0.060*** |
| | | | | | (0.021) | (0.021) |
| Genre F.E. | No | Yes | No | Yes | No | Yes |
| Rating F.E. | No | Yes | No | Yes | No | Yes |
| Observations | 3776 | 3776 | 2981 | 2981 | 3464 | 3464 |
| Adjusted $R^2$ | 0.057 | 0.073 | 0.097 | 0.110 | 0.056 | 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 A2: Probability of Adoption (Main Specification Using Probit)

| | (1)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital | (5)<br>digital | (6)<br>digital |
|---|---|---|---|---|---|---|
| # Previous films (IHS) | -0.098*** | -0.071** | | | | |
| | (0.029) | (0.030) | | | | |
| Previous Movie Revenue (IHS) | | | -0.050*** | -0.030** | | |
| | | | (0.012) | (0.013) | | |
| Only One Prev. Movie | | | | | -0.222*** | -0.191** |
| | | | | | (0.079) | (0.081) |
| Only two previous movies | | | | | -0.394*** | -0.361*** |
| | | | | | (0.100) | (0.102) |
| >2 Prev. Movies | | | | | -0.248*** | -0.182*** |
| | | | | | (0.067) | (0.069) |
| Genre F.E. | No | Yes | No | Yes | No | Yes |
| Rating F.E. | No | Yes | No | Yes | No | Yes |
| Observations | 3776 | 3766 | 3776 | 3766 | 3776 | 3766 |

Notes: year fixed effects included, robust errors in parenthesis. This table presents regression results for the main specification 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 4 and 5 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 A3: Probability of Adoption (Dropping G Rated movies)

| | (1)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital | (5)<br>digital | (6)<br>digital |
|---|---|---|---|---|---|---|
| # Previous films (IHS) | -0.017*** | -0.011** | | | | |
| | (0.005) | (0.005) | | | | |
| Previous Movie Revenue (IHS) | | | -0.009*** | -0.009*** | | |
| | | | (0.002) | (0.002) | | |
| Only One Prev. Movie | | | | | -0.039*** | -0.032** |
| | | | | | (0.014) | (0.014) |
| Only two previous movies | | | | | -0.067*** | -0.057*** |
| | | | | | (0.016) | (0.016) |
| >2 Prev. Movies | | | | | -0.043*** | -0.030** |
| | | | | | (0.013) | (0.013) |
| Genre F.E. | No | Yes | No | No | No | Yes |
| Rating F.E. | No | Yes | No | No | No | Yes |
| Observations | 3742 | 3742 | 3742 | 3742 | 3742 | 3742 |
| Adjusted $R^2$ | 0.057 | 0.073 | 0.059 | 0.059 | 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 since no rated G films in are sample were filmed digitally. 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 4 and 5 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 (Controlling for Past Adoption)

| | (1) digital | (2) digital | (3) digital | (4) digital | (5) digital | (6) digital |
|---|---|---|---|---|---|---|
| # Previous films (IHS) | -0.027*** | -0.022*** | | | | |
| | (0.005) | (0.005) | | | | |
| Previous Movie Revenue (IHS) | | | -0.012*** | -0.012*** | | |
| | | | (0.002) | (0.002) | | |
| Only One Prev. Movie | | | | | -0.053*** | -0.047*** |
| | | | | | (0.014) | (0.014) |
| Only two previous movies | | | | | -0.083*** | -0.073*** |
| | | | | | (0.016) | (0.016) |
| >2 Prev. Movies | | | | | -0.065*** | -0.052*** |
| | | | | | (0.012) | (0.012) |
| Top Production | | | | | | |
| 1Past Adopt | 0.315*** | 0.306*** | 0.309*** | 0.309*** | 0.314*** | 0.306*** |
| | (0.043) | (0.042) | (0.043) | (0.043) | (0.043) | (0.042) |
| Genre F.E. | No | Yes | No | No | No | Yes |
| Rating F.E. | No | Yes | No | No | No | Yes |
| Observations | 3776 | 3776 | 3776 | 3776 | 3776 | 3776 |
| Adjusted $R^2$ | 0.090 | 0.104 | 0.091 | 0.091 | 0.092 | 0.106 |

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 4 and 5 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 Other Experience)

| | (1)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital |
|---|---|---|---|---|
| # Previous films (IHS) | -0.022*** | | -0.015*** | |
| | (0.006) | | (0.006) | |
| Only One Prev. Movie | | -0.042*** | | -0.035** |
| | | (0.014) | | (0.014) |
| Only two previous movies | | -0.074*** | | -0.063*** |
| | | (0.016) | | (0.016) |
| >2 Prev. Movies | | -0.055*** | | -0.039*** |
| | | (0.013) | | (0.014) |
| # Prev. Credits (IHS) | 0.009** | 0.009* | 0.007 | 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 | 3776 | 3776 | 3776 | 3776 |
| Adjusted R-squared | 0.058 | 0.060 | 0.073 | 0.075 |

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 probability 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 A6: Probability of Adoption (Results Using the Full Sample)

| | (1)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital | (5)<br>digital | (6)<br>digital |
|---|---|---|---|---|---|---|
| # Previous films (IHS) | -0.015*** | -0.009** | | | | |
| | (0.005) | (0.005) | | | | |
| Previous Movie Revenue (IHS) | | | -0.008*** | -0.004** | | |
| | | | (0.002) | (0.002) | | |
| Only One Prev. Movie | | | | | -0.039*** | -0.033** |
| | | | | | (0.014) | (0.014) |
| Only two previous movies | | | | | -0.068*** | -0.058*** |
| | | | | | (0.016) | (0.016) |
| >2 Prev. Movies | | | | | -0.043*** | -0.029** |
| | | | | | (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 | 0.062 | 0.077 |

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 4 and 5 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 A7: Probability of Adoption among first-timers as a function of previous industry experience.

| | (1)<br>digital | (2)<br>digital | (3)<br>digital | (4)<br>digital |
|---|---|---|---|---|
| # Prev. Credits (IHS) | -0.001<br>(0.008) | | | |
| Top (quart) Prev. Credits | | -0.010<br>(0.026) | | |
| # Actor Credits (IHS) | | | 0.000<br>(0.006) | |
| Top (quart) Actor Credits | | | | -0.022<br>(0.022) |
| Genre F.E. | Yes | Yes | Yes | Yes |
| Rating F.E. | Yes | Yes | Yes | Yes |
| Observations | 1470 | 1470 | 1470 | 1470 |
| Adjusted R-squared | 0.083 | 0.083 | 0.083 | 0.083 |

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 credit 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 A8: Probability of Adoption Controlling for Budget Decile by Year Fixed Effects

| | (1) | (2) |
|---|---|---|
| | digital | digital |
| First Movie | 0.051** | 0.044* |
| | (0.024) | (0.024) |
| BudgetXYear F.E. | Yes | Yes |
| Genre F.E. | No | Yes |
| Rating F.E. | No | Yes |
| Observations | 873 | 873 |
| Adjusted $R^2$ | 0.083 | 0.095 |

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 A9: Standard Deviation of Film Returns by Rating and Director Experience

| Rating | Prev. Films | Digital | 1998-2009 Full | 2001-2009 Full | 1998-2009 Winsor | 2001-2009 Winsor |
|---|---|---|---|---|---|---|
| G | 0 | No | 1.144 | 1.494 | 1.144 | 1.494 |
| G | 1+ | No | 5.650 | 6.298 | 5.742 | 6.298 |
| PG | 0 | No | 15.153 | 17.006 | 3.072 | 2.215 |
| PG | 0 | Yes | 35.887 | 35.887 | 1.662 | 1.662 |
| PG | 1+ | No | 5.586 | 6.120 | 1.747 | 1.786 |
| PG | 1+ | Yes | 53.512 | 55.097 | 2.612 | 2.199 |
| PG13 | 0 | No | 8.252 | 9.111 | 2.770 | 2.872 |
| PG13 | 0 | Yes | 6.720 | 6.720 | 2.945 | 2.945 |
| PG13 | 1+ | No | 2.529 | 2.529 | 2.271 | 2.210 |
| PG13 | 1+ | Yes | 3.761 | 3.761 | 3.761 | 3.761 |
| R | 0 | No | 283.837 | 9.215 | 3.834 | 4.306 |
| R | 0 | Yes | 1,458.914 | 1,487.801 | 5.680 | 5.567 |
| R | 1+ | No | 8.036 | 9.229 | 2.512 | 2.488 |
| R | 1+ | Yes | 3.883 | 3.940 | 3.931 | 3.991 |
| Unrated | 0 | No | 3.232 | 3.294 | 3.266 | 3.339 |
| Unrated | 0 | Yes | 11.672 | 11.858 | 6.844 | 6.939 |
| Unrated | 1+ | No | 8.100 | 8.413 | 2.273 | 2.350 |
| Unrated | 1+ | Yes | 1.469 | 1.498 | 1.479 | 1.506 |

Notes: this table reports the standard deviation of move returns for each camera type by film rating, previous director experience, and period. Film returns are defined as the difference between worldwide gross revenue and the budget relative to the budget, as reported in IMDb. Columns 4 and 5 report the standard deviation for the full sample. Columns 6 and 7 show the standard deviations after winsorizing the data at the top and bottom one percent of returns.