Switching off: empirical evidence for labour automatisation and obsolescence rents in the US telephone switchboard industry.

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1 Summary

This paper uses the Obsolescence Rents model proposed by [Cavounidis et al., 2022] to investigate the impact of electronic automatic switchboard on labour market for the manual telephone switchboard operators. After the introduction of electric automatic switchboard in 1964, the US wages for manual switch operators increased despite the known future collapse of that job market, while the average age of workers increased. This indicates that both obsolescence rents and anticipatory dread occurred in the industry. The aim of the essay is to provide empirical evidence on labour market behaviour in industries that experience systematic technological changes and automatisation

2 Introduction

Historical views traced back to creative destruction [Schumpeter, 1994] suggest the effect of creative destruction in replacing given occupations or markets by emerging technologies. Textile workers replaced by machinery in the 19th century [Hobsbawm, 1952] or Polaroid cameras replaced by digital photography [de Figueiredo and Kyle, 2006] are well-documented examples of creative destruction. Importantly, with the contemporary rapid technological growth, numerous labourers are exposed to similar forces, from truck drivers [Cavounidis et al., 2022] to industrial workers or healthcare personnel [Acemoglu and Restrepo, 2018]. The motivation behind this essay is to provide economists and policymakers with further evidence on market and labour behaviour under structural, technological changes. I first present the history of the telephone switchboard industry. Then we present the methodology to model Obsolescence Rent. Finally, I present the results of the study and demonstrate that rapid hardware automatisation has counterintuitively led to short-term rent increases.

2.1 History of the Telephone Switchboard Industry

When the telephone was first introduced in 1876 by Alexander Bell, the existing phone line was limited only to two speakers by the end of the existing cable. In response to the direct connection problem, in 1877 Holmes Burglar Alarm Company in Boston introduced the first telephone switchboard that allowed the connection of more than two telephone lines together [Thompson and Hill, 1930]. The switchboard was operated manually by *switching* and connecting the existing cable lines (Fig 1).

While the telephone industry, with enterprises such as AT&T or Bell Systems, grew and evolved, the job of switchboard operator remained crucial in connecting the growing grids across the entire country.

In 1903 Bells Systems acquired a patent for the Lormier automatic switchboard. The system allowed automatic switching without hand-by-hand involvement [Nix and Gabel, 1996]. By 1910s out of 11 million subscribers total, around 300 000 telephone subscribers had automatic services [Price, 2019]. The majority of these services were offered by regional providers, outside of big metropolitan centres. Only in 1921 Bells Systems introduced the first automatic switchboard in a large city. By the 1930s, a third of the switchboards of the operator were automatic [Nix and Gabel, 1996]. Direct Distance Dialing was introduced at the beginning of 1940s.

In the 1950s the switchboard employment peaked at 342 000 workers. In 1960 in Morris, Illinois, a first fully Electronic Automatic Switchboard, was undergoing early trials [BST, 1965]. Although the technology of automatic switchboard was known from the 1903, with electric switchboard, it was deliberately not introduced because of its technological limits in large cities. Every new connection required to be added to the existing infrastructure, which drove up the costs per each added customer. In a simplification, 7 customers required to be connected to each other, giving us 49 required interconnectors. A grid of 8 customers required 64 interconnectors [Price, 2019]. Therefore, due to diseconomies of scale, the electric automatic switchboard was not competitive to manual switchboard in large urban areas. As [Mueller, 1989] argues *You didn't get entirely out of the telephone scaling problem until digital [electronic] switching in the 1960s.*

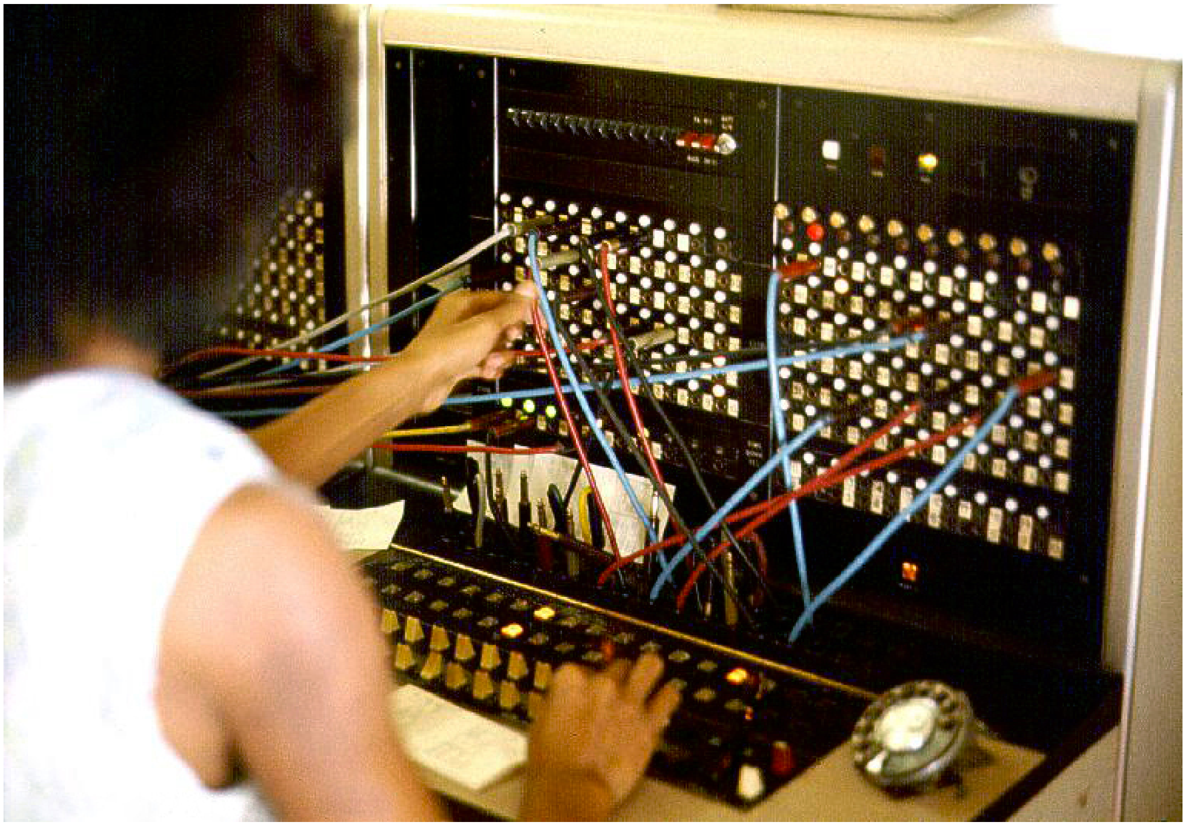

Figure 1: Jersey Telecom telephone operator at switchboard, 1975

2.2 The Beginning of the end

As the technological, economic and logistical limitation of the automatic switchboard was known, manual operators were expected to maintain their crucial function in interconnecting the urban areas. In 1964 an economist Elizabeth Faulkner Baker wrote "*It is possible that the decline in the relative importance of telephone operator may be nearing an end*" and "*in the foreseeable future no machines will be devised*" (to replace the manual operators) [Baker, 1964]. However, the same year New York Times published an article "A Shift to All-Electronic Phones Begun in Biggest Step in Dial" saying "*The Bell System has already spent more than $100 million to develop electronic switching. A test of it has been made in a small exchange in Morris, Ill. A second test involving 200 subscribers, will be made in mid-1965 in Succasunna, N.J.*" [New York Times, 1964]. The Succasunna system, which was the first commercial electronic switchboard, started operating in 1965, against the predictions of contemporary experts, and validated the electronic technology. : "*Young men operated the boards and it was found that they could reach to three boards, accommodating 150 lines while the machine* (The electronic switchboard) *serving Pennsylvania will handle 7,000 lines using 54,000 transistors* [New York Times, 1964]. Furthermore, while the machine required upfront, capital investment, manual switchboard operators needed to be paid and maintained: *the companies catered to their operators with libraries, athletic clubs, free lunches, and disability plans. Operators took their breaks in tastefully appointed, parlor-like break rooms, some with armchairs, couches, magazines, and newspapers. At some exchanges, the companies provided the operators with a community garden in which they could grow flowers or vegetables*. Price2019. Apart from decreasing the total and marginal costs, electronic switchboards increased the satisfaction rates of the subscribers. A survey conducted by AT&T [Nix and Gabel, 1996] indicates that already in 1904 customers preferred automatic switchboards to manual operators. Therefore, businesses were heavily incentivised to exchange manual operators with electronic automatic switchboards.

Therefore, with the introduction of automatic switchboard, the manual job has become unexpectedly uncompetitive and obsolete. In 1964 the end of the switchboard operator industry has begun.

Table 1. Results From Customer Survey, 1904

Which telephone do you prefer to use:

	Dayton	Fall River	New Bedford
Automatic	63.3%	56.6	68.5
Bell	8.3	36.1	20.5
No preference	28.4	7.3	11.0

Sources: "Tests of the Strowger Automatic System in Chicago, Illinois," October 18th, 1904, AT&TCA file no. 11 07 01 02; "Tests of the Strowger Automatic Telephone System at Dayton, Ohio," November 3, 1904, AT&TCA file no. 11 07 01 02; "Tests of the Strowger Automatic System at New Bedford, Mass," September 28, 1904, AT&TCA file no. 11 07 01 02; "Tests of the Strowger Automatic Telephone System at Fall River, Mass," October 20, 1904, AT&TCA file no. 11 07 01 02.

Figure 2: Results from Customer Survey [Nix and Gabel, 1996]

In 20 years, the number of manual switchboard operators declined to 40 000 people replaced by first electronic automatic switchboards and later satellite connection [Price, 2019]. Today, in the US there are 1,460 employed in "operator" rank [U.S. Bureau of the Census, 1976].

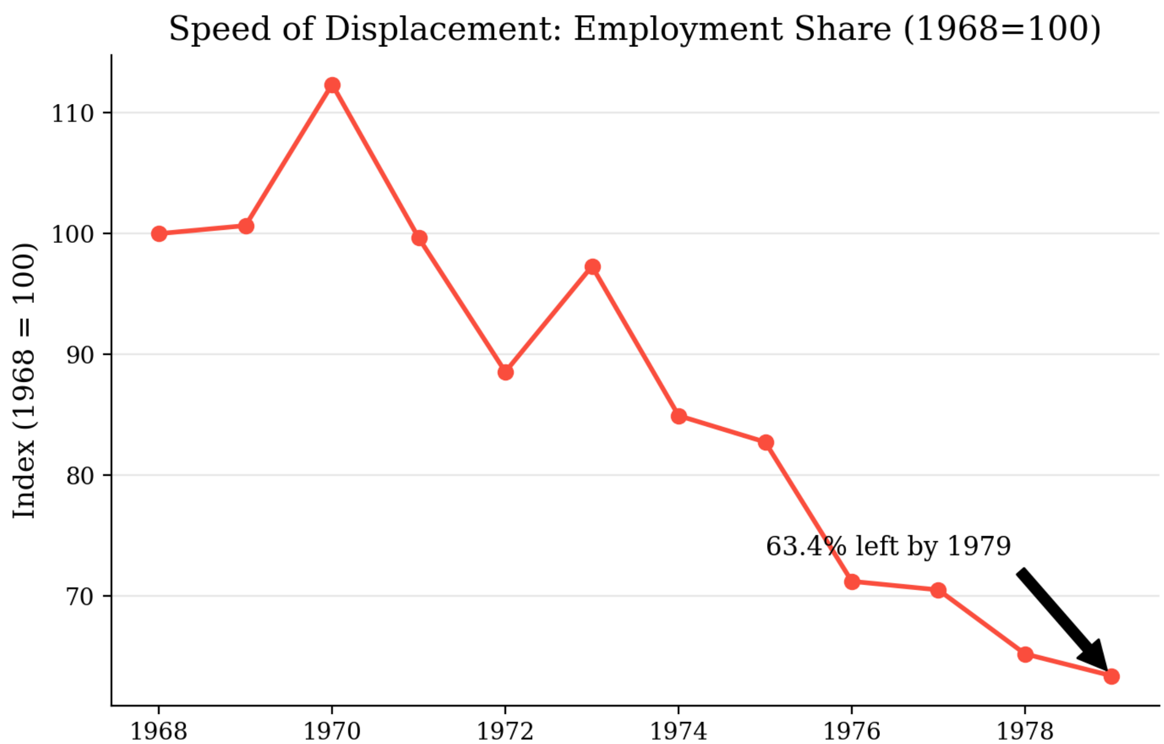

Figure 3: Speed of Displacement. Employment share indexed to 1968=100[2]. By 1979, only 63% of the share remained. [IPUMS USA, 2023a]

3 Methodology

As [Acemoglu and Restrepo, 2019]argue the presumption that all technologies increase (aggregate) labor demand simply because they raise productivity is wrong. Originally, [Cavounidis et al., 2022] propose a simple overlapping generations (OLG) model to demonstrate rational and forward-looking behaviour of workers in labour-intensive industries that experience structural changes. They use the example of US Teamsters, who drove teams of horses that pulled wagons, at the dawn of the automotive truck [Cavounidis et al., 2022]. Expecting the market for teamsters to be exchanged by automotive truck, some young labourers decided not to enter the market, creating an anticipatory dread, where the market experienced undersupply of labour. As no new labourers were joining the teamster market, the general average age of labourers increased after the shock. However, those who decided to enter the market gained bargaining power and could benefit from obsolescence rent, as operators needed to maintain their businesses. In this paper, I investigate whether similar phenomenons occurred in the US telephone switchboard operators' market, i.e whether the

1. average age of labourer increased, indicating the decline in labour supply in the market and anticipatory dread,
2. average wage per capita increased, indicating the obsolescence rent. after the introduction of the electronic automatic switchboard in 1964.

Following [Cavounidis et al., 2022], I use a simple overlapping generations (OLG) model. The model assumes individuals choose their occupation once, cannot change their occupation after the shock and have limited ability to change their occupation in a longer period of time (i.e. due to specific set of skills or age). Each individual lives and works in two periods in order to separate "young" and "old" workers prior and post of the external shock and have the same productivity levels.

The *wage function* is denoted before the shock $w_h(\cdot)$ and after the shock $w_l(\cdot)$. The external event, such as introducing electronic automatic switchboard, creates a negative wage shock:

$$w_h(x) < w_l(x)$$

for all workers.

Therefore, using a utility function, a worker decides to enter the given labour market if:

$$(w_t - \vartheta) + \delta\big(E(w_{t+1}) - \vartheta\big) > 0.$$

where $w(t)$ denotes the current wage, $E[w(t+1)]$ is the expected future wage discounted by γ, and ω represents the random disutility from entering the given labour market. The term ω allows for heterogeneous utility preferences across workers when deciding whether to enter the labour market. There are three stages in the model:

1. **No-shock (N)**: Workers assume the technology is stable. $E_t[w_{t+1}] = w_N$. The explicit wage w_N clears the market with stable demand D.

   $$S^Y(w_N, w_N) + S^O = D(w_N)$$

   This corresponds to the period before a new *quality rung* is discovered in the Aghion-Howitt framework [Aghion and Howitt, 1998]. The arrival *rate of innovation* at this stage is perceived to be zero ($\lambda = 0$).

2. **Anticipatory Dread (D)**: An announcement or realization occurs at time t that the technology will become obsolete in the future (at time $T > t$). Workers update their expectations: $E_t[w_{t+1}] = w_L < w_N$, where w_L is the depressed wage in the obsolescence phase. In [Aghion and Howitt, 1992], the arrival of an innovation is a stochastic process with probability λ. Here, the "Dread" stage represents a period where λ spikes—the probability of substitution becomes non-negligible. Since $w_L < w_N$, the expected lifetime income drops. The threshold θ^D falls:

   $$\theta^D = \frac{w_D + \delta w_L}{1+\delta} < \theta_N^*$$

   Consequently, fewer young workers enter (S_t^Y falls).

3. **Obsolescence Rent Result**: If demand $D(w)$ is inelastic in the short run (manual operators are still needed until the machines are fully installed), the reduction in supply ($S^Y \downarrow$) requires the current wage w_D to rise to clear the market.

   $$w_D > w_N$$

   This premium ($w_D - w_N$) is the obsolescence rent. It is paid to retain/attract enough workers despite the "dread" of the future collapse.

4. **Aftermath (A)**: The technology arrives fully. Demand collapses. Wages fall to w_L. S^Y drops further or goes to zero.

These three stages have unique steady states, which gives the opportunity to compare different employment and wage levels between each other [Cavounidis et al., 2022]. As the given market is not attractive, new workers decide not to enter the market and the employment falls from N-stage to A-stage as the expected future wages fall from w_t to w_l:

$$o_N^* > o_D^* > o_A^*$$

As provided by [Cavounidis et al., 2022] the *obsolescence rent* can be formulated as:

$$w_h(2o_D^*) > w_h(2o_N^*) > w_l(2o_A^*)$$

or graphically represented as:

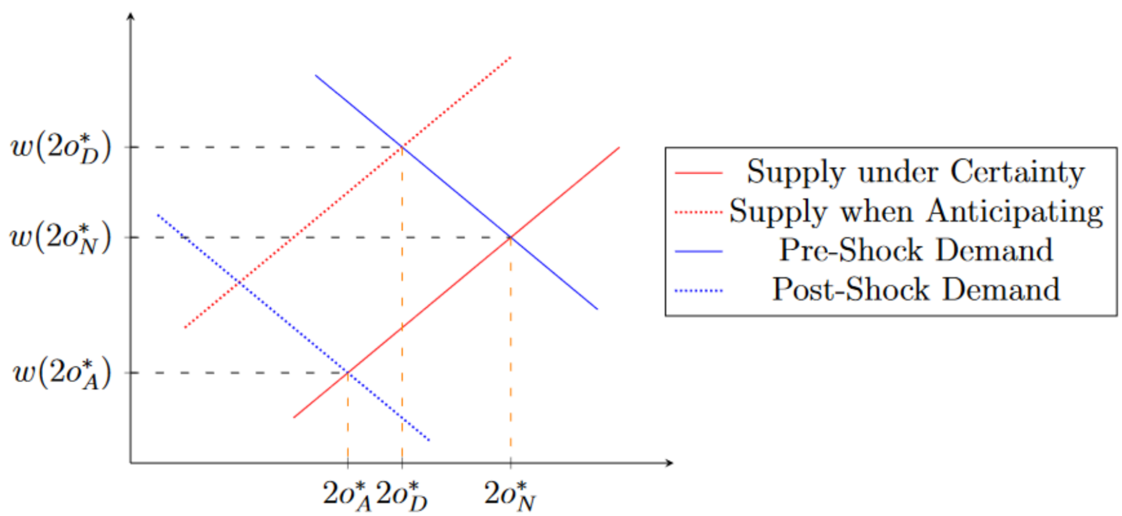

Figure 4: No-shock (N), anticipatory dread (D) and aftermath (A) steady states as by [Cavounidis et al., 2022]

As the number of workers willing to enter the market decreases from $2O_N^*$ to $2O_A^*$, the supply curve shifts to the left. As a result, employment declines while wages rise to $w(2O_D^*)$. When demand for the given goods and services catches up (the A-stage), wages fall and the new steady state is reached at $2O_A^*$. Similar approaches of forward-looking labourers can also be found in [Hobijn et al., 2019], who investigate retraining frictions. [Barany and Siegel, 2018] argue agents decide on their jobs based on current and future wages, or [Cavounidis and Lang, 2020] who model the reaction of labourers to external shocks which increase value of given skills and decrease the others in a given labour market. Following the endogenous growth framework of [Aghion and Howitt, 1998], we can view the switchboard industry's collapse not as an isolated tragedy but as a necessary condition for the *quality ladder* ascent of the telecommunications sector.

In the [Aghion and Howitt, 1998] framework, we can view the automatic switchboard as a classic *intermediate good*, an input into the production of final good: communication. The electronic switchboard represents a higher *rung* on the quality ladder ($q_{t+1} > q_t$) fully replacing the previous (manually-operated) technology. Firms, which needed time to replace incumbent technology, were forced to pay a premium to continue it's operations just long enough to complete the technological transition.

As demonstrated[3] by [Price, 2019] and [Baker, 1964], we can assume the introduction of electronic automatic switchboard as an external shock that could not be predicted by young workers deciding on

[3]However, it is worth noting that an incorrect prediction of an economist may not reflect the opinion or knowledge of the whole labour market

their occupation. Therefore, the year 1964 can be assumed as a benchmark to estimate the statistical significance of introducing the electronic automatic switchboard on the switchboard operator market and whether *anticipatory dread* and *obsolescence rent* can be identified.

3.1 Controls

It is necessary to investigate whether the decline in number of manual operators may be caused by elements outside of the model i.e. other technologies replacing switchboards, demographics, historical episode such as war etc. When it comes to technological competition, telephone lines were advantageous to all other existing forms of communications. The other available technology, the telegraph became uneconomic against the telephone long before the 1960s, as the cost of sending a message was substantially higher.

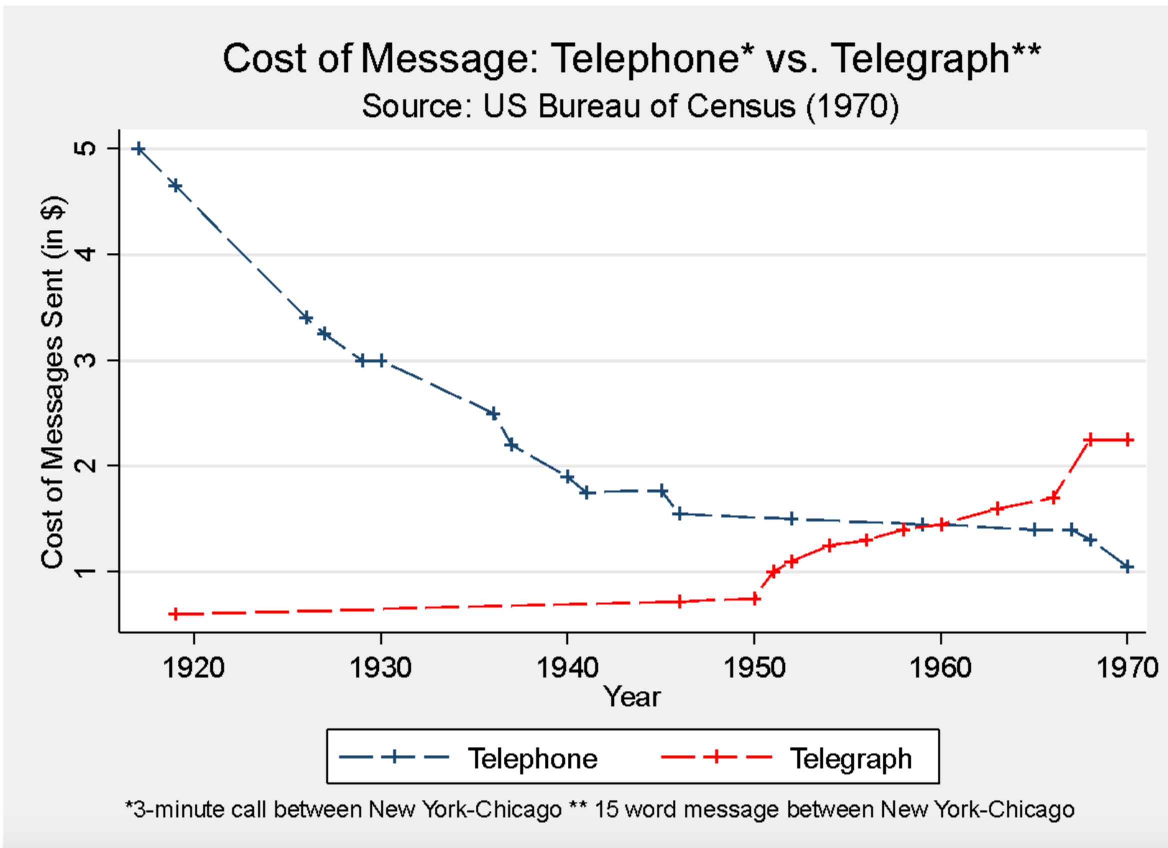

Figure 5: Cost of message: Telephone vs Telegraph[4] [U.S. Bureau of the Census, 1976]

Accounting for demographics and economic performance, I use the average switchboard wage relative to the general average wage in the US to accounts for inflation, GDP increase or competitive occupancies within the Labour market. This strategy, to an extent, can mitigate the potential econometrics issues.

4 Results

Figure 6 demonstrates the fall of the number of switchboard operators as a share of the US labour market. As a measure of control, I introduce the 1903 point where the electric automatic switchboard was introduced. However, as explained previously, the economic and logistics required to operate first automatic switchboards were disadvantageous to manual labour and hence did not impact the overall trend of the market. Figure 5 demonstrates the full lifecycle of the switchboard operator profession. We see the rise from 1910, the peak in 1950 (reaching 0.66% of all US employment), and the rapid collapse after the 1964 as automatic switchboard rapidly replaced the manual operators.

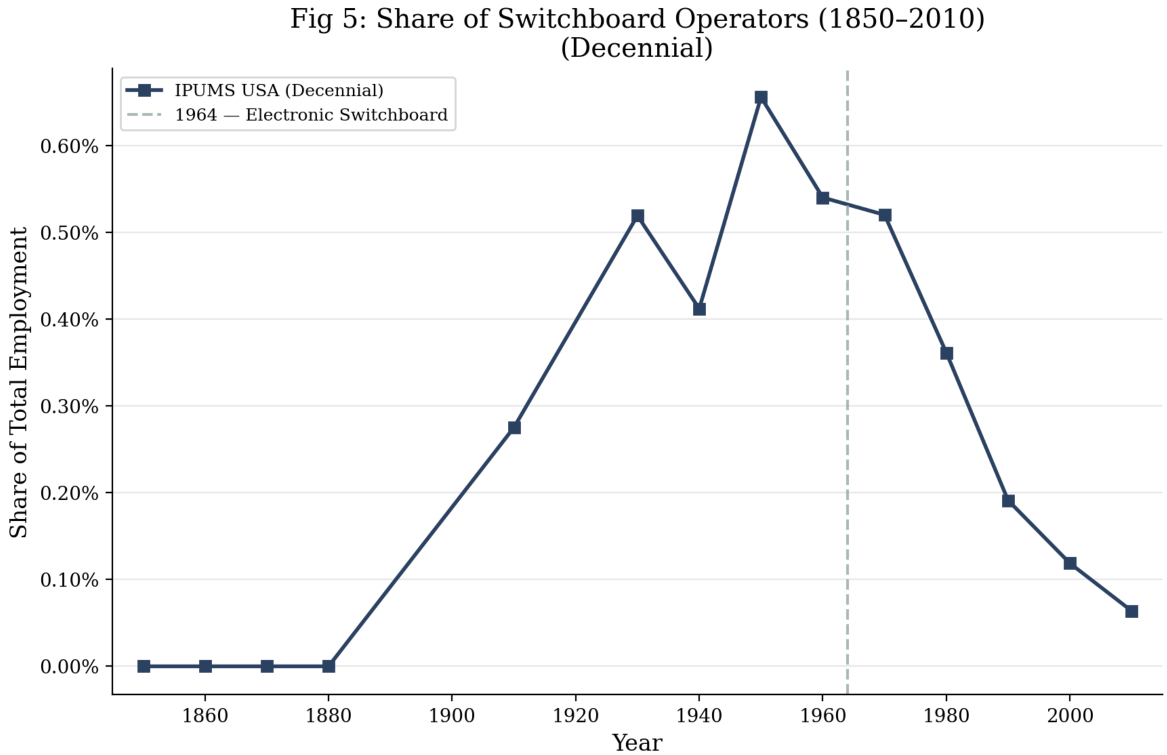

Figure 6: Share of Switchboard Operators in US Employment (1850–2010). The vertical line marks the 1964 introduction of electronic switching [IPUMS USA, 2023b] [IPUMS USA, 2023c].

Figure 7 demonstrates the increasing average age of the workers after 1964, which indicates that younger workers opted out from joining the switchboard operating market. The relative average age further indicates that the characteristics of switchboard operators changed in comparison to general working population. It indicates that the case for anticipatory dread can be made, as the model suggests.

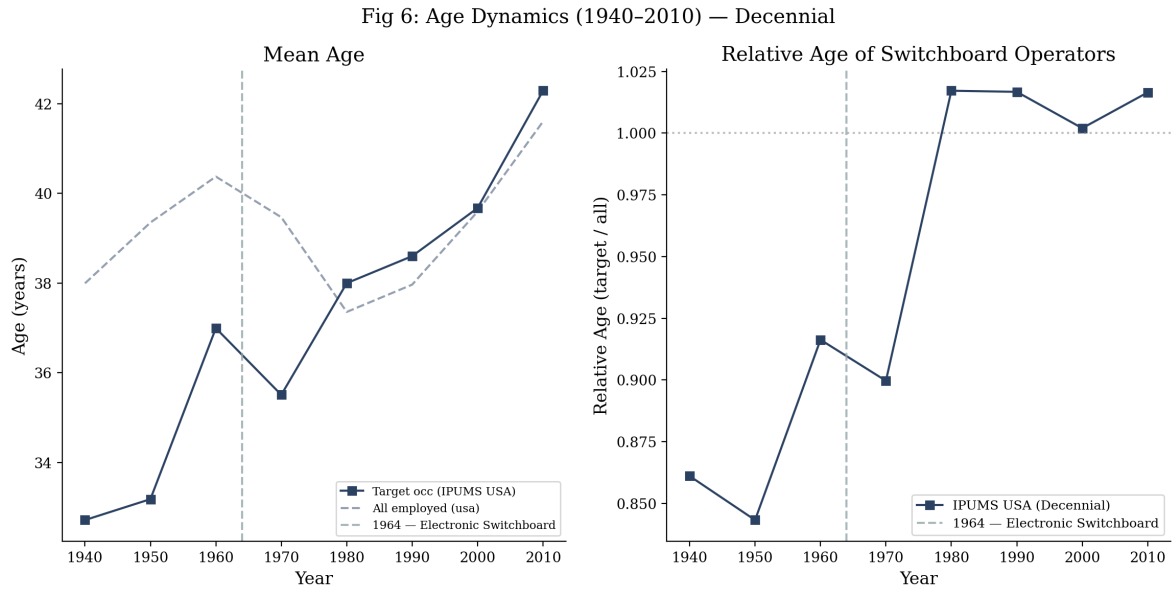

Figure 7: Mean and Relative age switchboard operators [IPUMS USA, 2023c]

Finally, figures 8 and 9 demonstrate the increased wages for switchboard operators relative to the average wage in the United States. We can observe a spike in wage ratio relative from the late 1960s, which indicates the obsolescence rent as the wages needed time to adjust to new market conditions while firms had to pay a premium to retain workers in a dying field..

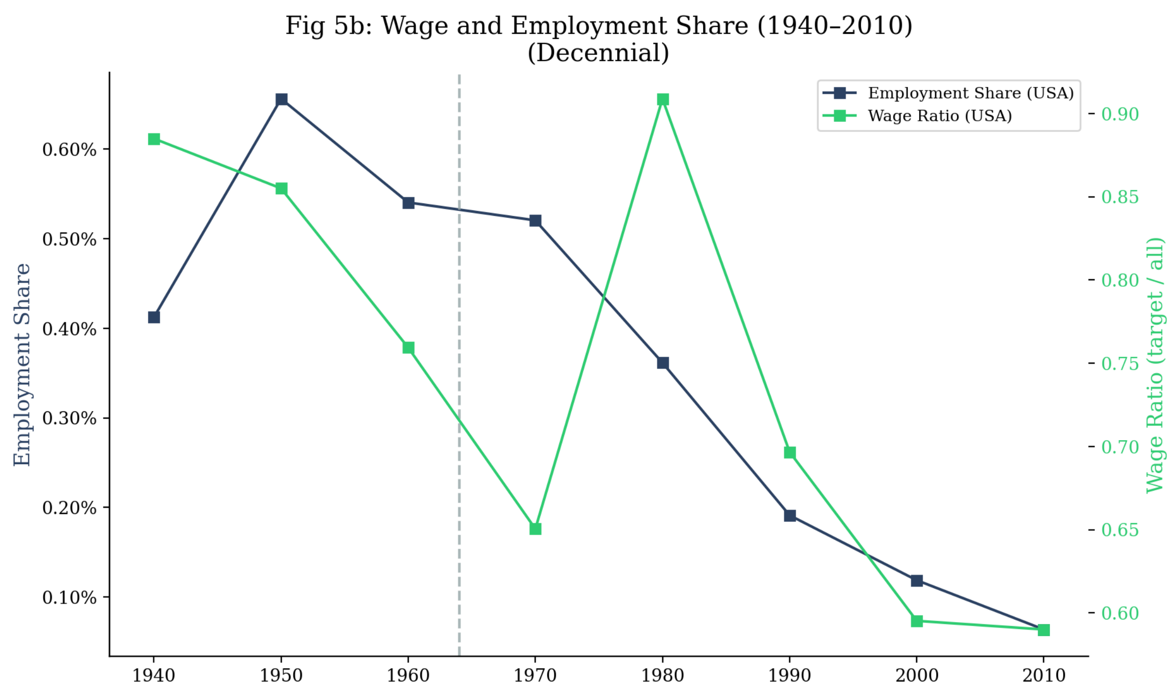

Figure 8: Switchboard Operators Wages and Employment Share (1940–2010) where employment collapses while relative wages exhibit premium behavior [IPUMS USA, 2023a].

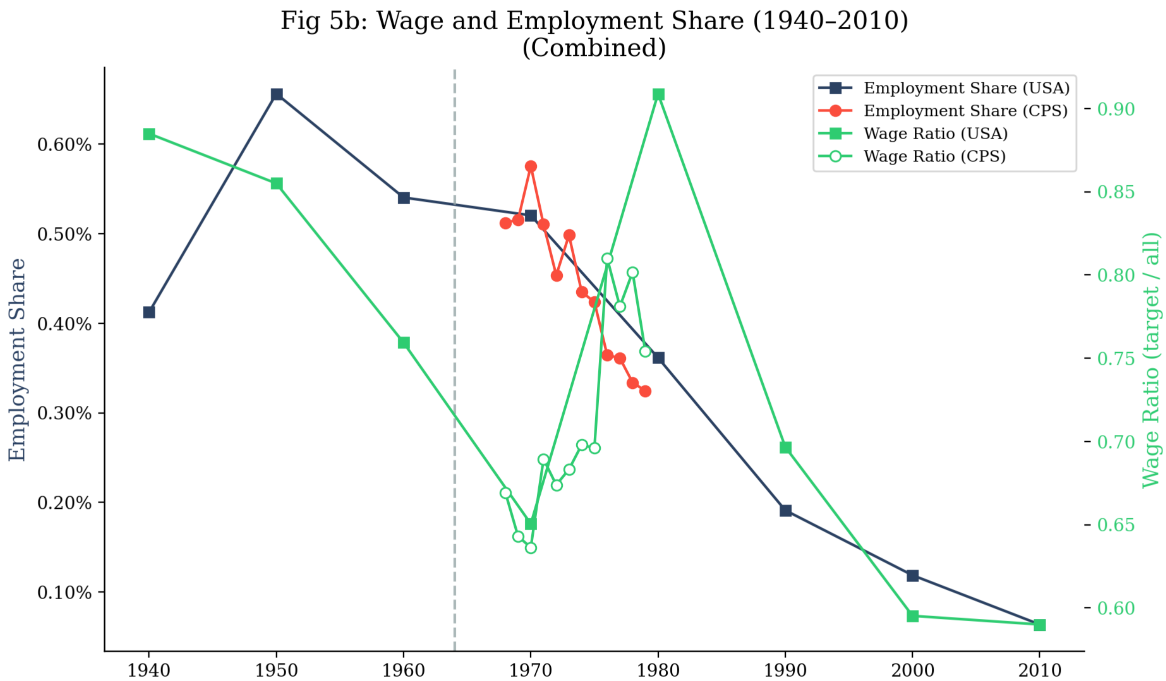

Figure 9: Switchboard Operators Wages and Employment including annual data from [IPUMS USA, 2023a]

5 Conclusion

The paper aimed to demonstrate anticipatory dread and obsolescence rent theoretically laid by [Cavounidis et al., 2022], in the US manual switchboard operators industry. The historical data, provided by [IPUMS USA, 2023a] and [U.S. Bureau of the Census, 1976], indicates that the industry experienced structural changes around 1964 when the first electronic automatic switchboard was introduced. In reaction to that external shock, people entering the labour market opted out from choosing the switchboard industry to alternative occupations, as proposed by the model in [Cavounidis et al., 2022]. As a result, the average age of the operator increased while the employees could temporarily benefit from the obsolescence rent as the average wage increased relative to the general US average wage. Further research would potentially require comparing different US states and countries, taking into account unions, and extending the econometric investigations. Currently, AI adoption [Acemoglu and Restrepo, 2018] and it's potential impact on market structure [Aghion et al., 2017] provides lot's of speculation. This paper gives a theoretical and historical reasons to predict that fast, unexpected innovation with potential to replace entire specialised hardware jobs could counter-intuitively result in short-term wage increases.

6 Appendix

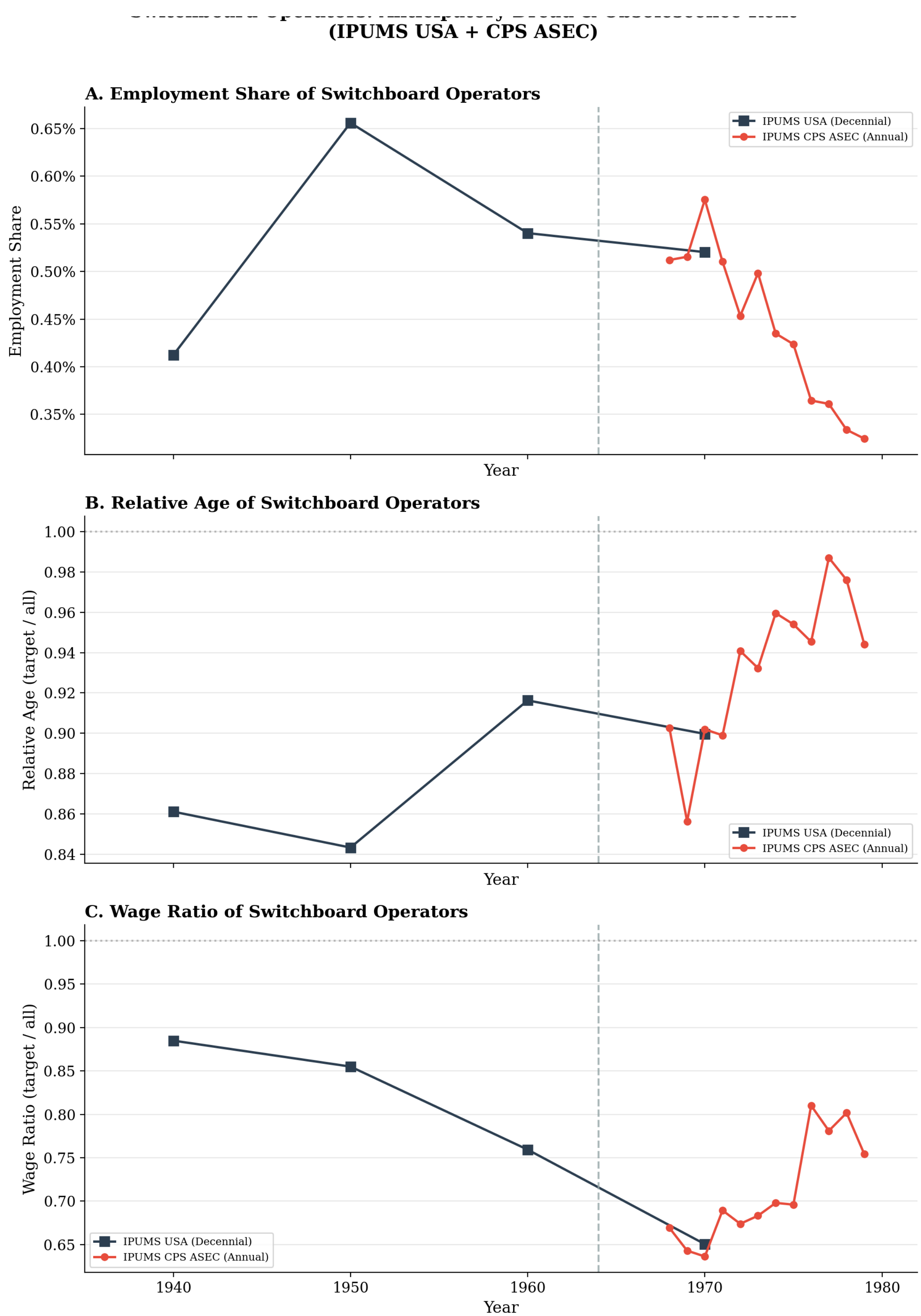

Figure 10: Summary graphs for Switchboard Operator Industry [IPUMS USA, 2023a]

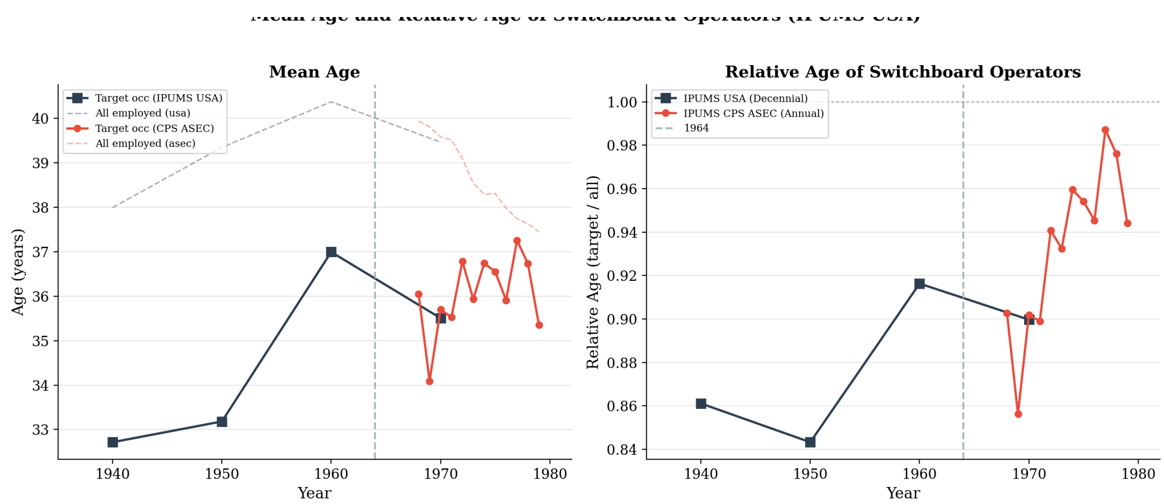

Figure 11: Mean Age of Switchboard operator[IPUMS USA, 2023a]

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