Was There a Hawthorne Effect?

Stephen R. G. Jones

McMaster University

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Abstract

The "Hawthorne Effect" has been the most enduring legacy of the celebrated studies of workplace behavior conducted in the 1920s and 1930s at the Hawthorne plant of the Western Electric company. Paradoxically, it is not clear that this effect constituted more than an incidental and intermediate finding for the original researchers. This paper examines the empirical evidence for Hawthorne effects using the original data from the Hawthorne Relay Assembly Test Room, where a group of workers was closely studied, with a variety of experimental and other changes in the work environment, over a period of more than five years. Using both narrow and broad definitions of an experimental change and allowing for other factors and for potential interdependence of the workers' output levels, I assess whether such experimental changes had a common effect that could be regarded as a pure result of the experimentation. The main conclusion is that there is only slender evidence of a Hawthorne effect in the Hawthorne Relay Assembly Test Room.

Was There a Hawthorne Effect?

The most enduring legacy of the celebrated studies of workplace behavior conducted at the Hawthorne plant of the Western Electric Company in the 1920s and 1930s is the so-called "Hawthorne Effect." Variously defined, the central idea is that behavior recorded during the course of an experiment can itself be altered by a subject's awareness of participating in the experiment. Though not obviously more than an incidental and intermediate finding for the original researchers, the Hawthorne Effect has come to occupy a central role in the methodology of experiments and continues to have widespread influence, both in psychology textbooks and in research, especially research in the psychology of education. Somewhat surprisingly, although efforts have been made to identify Hawthorne effects in various areas of field experimental research, there has been no systematic study of the evidence from the Hawthorne plant itself. The object of this paper is to undertake such a study, recognizing the mixed experimental and field nature of the Hawthorne research.

The paper first reviews the widespread and largely uncritical acceptance of the idea of a Hawthorne effect, especially in the psychology literature. It then examines the evidence from the Hawthorne studies themselves, with allowance for a wide range of direct experimental and incidental variables, for the role of replacement workers during the five years of study, and for potential interdependence of the workers' output levels.

Whether the Hawthorne effect is defined in a narrow or a broad sense, the conclusion is broadly the same: that the original Hawthorne studies contain little clear evidence of a Hawthorne effect.

Influence of The Hawthorne Effect

Writing in the widely influential Festinger & Katz (1953) volume, French noted that a potential merit of field experiments over laboratory experiments is that the former can avoid or minimize artificiality and thereby overcome the problem of generalizing results from the laboratory to real-life situations. French (1953) continued:

> That this is not always the case, however, is well illustrated in the famous Hawthorne experiment. From a methodological point of view, the most interesting finding was what we might call the "Hawthorne effect." In order to manipulate more precisely the physical factors affecting production, the experimenters had set up a special experimental room for a small group of girls who were wiring [*sic*] relays. This wiring was separated from the rest of the factory, and the girls working in it received special attention from both outside experimenters and the management of the plant. Careful studies of this wiring group showed *marked increases in production which were related only to the special social position and social treatment they received* [italics added]. (pp.100-101)

However, French gave no reference for these careful studies and only cited the original Roethlisberger & Dickson (1939) account--that does not contain any statistical analysis beyond bivariate correlations--so that the exact foundation for his statement is unclear.

Notwithstanding this, there can be little doubt that the Hawthorne effect has entered into the literature as a key fact to be reckoned with in many practical contexts. Whyte (1956), for example, writes of the Hawthorne studies:

> As experiment followed experiment... it became abundantly clear that physical changes were not the key. As in the earlier experiment, output did shoot ahead where conditions were changed, but so did output shoot ahead where no changes had been made. ...The researchers came to the conclusion that output shot up in both groups because in both groups the workers' participation had been solicited and this involvement, clearly, was more important that physical perquisites. The workers were a social system; the system was informal but what it really determined was the worker's attitude toward his [sic] job. (p.34)

Similarly, Ruch and Zimbardo (1971) write:

> No matter what the researchers did, productivity went up [italics added]. Even when work conditions were made worse than they were originally, the women worked harder and more efficiently. (p.372)

More recently, Blalock & Blalock (1982) similarly report that:

> Each time a change was made, worker productivity increased [italics added], leaving the impression that each change had a progressive effect. As a final check, the experimenters returned to the original unfavorable conditions of poor lighting, no rest pauses, and no incentive system. Seemingly perversely, productivity continued to rise. (p.72)

Some qualification is provided by Elmes, Kantowitz and Roediger (1985):

> With few exceptions, no matter what changes were made--whether there were many or few rest periods, whether the work day was made shorter or longer, et cetera--the women tended to produce more and more telephone relays... The workers knew that the experimenters expected the changes in working conditions to affect them, so they did. (p.225)

As these sources reveal, the received wisdom in psychology is that there were Hawthorne effects at the Hawthorne plant.

In several areas of active research, the Hawthorne effect has come to be a significant preoccupation for many scholars. In education research in particular, since Cook's (1962) classic work, and the subsequent contribution of Bracht & Glass (1968), there have been many studies that attempt to deal with Hawthorne effects. In their recent survey of 86 such studies, Adair, Sharpe and Huynh (1989a) give a mixed overall assessment of this work: their meta-analysis gives no grounds for a Hawthorne versus no-treatment control difference.[1] Yet the view that the original Hawthorne studies provide a firm foundation for the idea of a Hawthorne effect remains firmly entrenched in the literature. As Adair (1984) recently wrote,

> [T]he investigators began by changing the method of determining wages. During the experiment the investigators also manipulated, on different occasions and sometimes concurrently, the length and timing of rest periods, the length of the work week, the length of the work day, and whether or not the company provided lunch and/or beverage. Productivity seemed to increase regardless of the manipulation introduced [italics added]. (p.336)

The Hawthorne Experiments

The Hawthorne Studies and the Hawthorne Effect

The Hawthorne experiments were conducted at the Hawthorne plant of the Western Electric Company in the late 1920s and early 1930s, and involved a variety of different studies of workplace behavior. The illumination experiments, which initially sought to establish a physiological relationship between intensity of illumination and workplace efficiency, pre-dated the main Hawthorne studies themselves and showed that, in some instances, workers could maintain efficiency even under very low intensity of light, a finding that the researchers viewed as quite anomalous.[2] Indeed, Roethlisberger and Dickson (1939, p.17) even mention a sequence of experiments where an electrician pretended to alter lighting intensity--simply replacing bulbs by others of equal power--and where the women involved commented explicitly on their preference for the old or new illumination intensity. Overall, it was concluded, these experiments "failed to answer the specific question of the relation between illumination and efficiency" but, nonetheless, "they provided great stimulus for more research in the field of human relations" (Roethlisberger and Dickson 1939, p.18).

For quantitative research, a more valuable aspect of the Hawthorne studies was the Relay Assembly Test Room studies, where five women worked in a technologically independent way producing electrical relays.[3] This study covered 270 weeks from April 1927 to June 1932 and involved 24 different "experimental periods" of varying length in which working conditions were changed, sometimes by conscious design of the researchers, sometimes by practical expediency when faced with the declining 1930s economy. Table 1 details the timing of these periods and lists the principal changes made in each.

With respect to the Hawthorne effect, there is little direct evidence in the original research. Perhaps the clearest statement is that by Roethlisberger and Dickson (1939), reviewing the changes that occurred in the first seven periods of the Relay Assembly Room experiment:

> There were those changes introduced by the investigators in the form of experimental conditions;

> these were well noted and recorded. There was another type of change, however, of which the investigators were not so consciously aware. This was manifested in two ways; first, in a gradual change in social interrelations among the operators themselves...; secondly, in a change in the relation between the operators and their supervisors...From [the] attempt to set the proper conditions for the experiment, there arose indirectly a change in human relations which came to be of great significance in the next stage of the experiment [italics added]. (pp.58-59)

Together with the non-quantitative evidence from the illumination studies, it is these observations, more than anything else in the original Hawthorne accounts, that seem consistent with the interpretation of the Hawthorne effect proposed by French.

Interpretation of the Hawthorne Effect for Empirical Investigation

There are three potential views of the usefulness of the original Hawthorne data for studying the Hawthorne effect. The most restrictive of these holds that the general experimental effect is the key. Particular factors relating to the isolation of group from the rest of the plant, the "special attention" accorded to its members, and other persistent effects in the Relay Assembly Test Room are critical, in this view, and since there was only one such Test Room, with no control study, the Hawthorne studies yield essentially one data point. On this reading, the original data can at best be suggestive but can never resolve the issue of Hawthorne effects.

A less restrictive view, and one that seems consistent with the interpretations placed on the Hawthorne data by many of the authors cited above, is that the Hawthorne effect is related to the explicit changes in experimental periods, changes which where, of course, known to the workers concerned. In this light, one can look for a common effect on output associated with <u>any</u> such experimental period changes, making allowance for other effects from any experimental or environmental variables.

Finally, the broadest interpretation is that the Hawthorne effect might reasonably be related to <u>any</u> changes in experimental conditions, not just those that coincided with the major changes when the experimental period changes. Thus, one might also expect a change induced by a Hawthorne effect to result from a within-experimental period change in working conditions. As with the second view, the research strategy that arises from the broad interpretation is to look for some common effect at times when any experimental variable changes, controlling for the experimental variables themselves. The present paper investigates the consequences of the second and third of these approaches, which are termed the Narrow and the Broad definition of an experimental change, respectively.

<u>Data Description and Output Levels at Periods of Experimental Change</u>

The investigation begins with simple data description and then moves to more involved statistical models of output determination in the Relay Assembly Room. Summary statistics on all the data used in this study are given in Table 2.[4] The output variables for the eight women studied in the Relay Assembly Test Room, including the three replacements, are measured as the mean number of (standardized) relays produced per hour worked, averaged over a weekly measurement interval. Repair time and voluntary rest time are measured in minutes per week, as is the general (non-person-specific) Scheduled Rest Time. Small group pay is a dummy variable reflecting the introduction of a group piece rate based on the group of five workers under study, as opposed to pay based on average output in the plant as a whole: this change was made in week 8 (see Table 1 above). Other experimental variables with changes detailed in Table 1 and summarized in Table 2 were days/week, the use of replacement workers, a change in the seating plan at the workbench, and the number of scheduled rest stops.[5] A change in any of these variables in a week will count as a Broad experimental change, whereas a Narrow change is limited to those groups of simultaneous changes listed in Table 1. Overall, of the 270 weeks, 24 weeks had a Narrow experimental change, while 88 weeks had a Broad change.

The first set of results comes from a comparison of individual mean output levels overall, in the week of an experimental change, in the preceding week and in subsequent weeks; this is an "unconditional" interpretation of the Hawthorne effect, as suggested by several of the authorities cited above. These figures are given in Table 3. The first panel gives the Narrow definition results, while the second gives the Broad results; since different workers were present for differing periods, the sample size upon which the mean is based is given as the second figure in each cell. For each worker, the results display little evidence in favor of a simple Hawthorne effect. Relative to the week preceding the change, the pattern of mean outputs in the week of the change rises slightly on the Narrow definition but is mixed for the Broad changes. For subsequent weeks, there are more cases when output rises than when it falls, but the movement is once again slight. At conventional significance levels, one certainly could not reject the hypothesis that output had the same mean in each of the weeks surrounding the experimental change.

More generally, the pattern of output levels at <u>all</u> periods after an experimental change (and before the next such change) is graphed for the Narrow and Broad cases in Figures 1 and 2 respectively. As can be seen from Figure 1, although these is considerable diversity in the mean output levels of the workers involved, especially including the three replacement workers who had particularly low average output, there is a clear trend only for worker 4, and that only begins in the fifth week after a Narrow experimental change. For the Broad definition in Figure 2, worker 4 again has the strongest upward pattern in her mean output levels though, as with Figure 1, in no case is there a significant regularity in these mean output data.

Models of Worker Behavior and the Hawthorne Effect

One potential problem with these preceding results is that, since the experimental changes themselves are likely to have direct effects (such as from the introduction of small group incentives in period 3), these may obscure any Hawthorne effects that might be present. To control for this, I next present the results of estimating the determinants of individual output levels, controlling for the direct effects of experimental changes.

Two sets of specifications are employed. The first treats each worker's output as independent of the others, though potentially influenced by a set of common variables, and amounts to estimation of

$$q_i = X_i b + Z c + u_i \qquad (1)$$

where X_i are person-specific variables from Table 2 and Z are the variables common to all the workers. An alternative approach allows for sluggish response to experimental changes and a potential interdependence in the levels of output of the members of the working group by postulating

$$q_i = \lambda q_i(-1) + X_i\,b + Z\,c + \alpha q_{-i} + u_i \qquad (2)$$

where $q_i(-1)$ is the own lagged value of output and q_{-i} is a vector of contemporaneous output variables for the other members of the working group. This second model follows that developed in Jones (1990). In the former case, a single equation estimate is appropriate while for the latter the endogeneity of other workers' concurrent output levels means that an instrumental variable estimate is preferred: instruments used are lagged output levels and person-specific variables such as voluntary rest or repair time. Finally, in view of the role of replacement workers in the Relay Room, a variant of model (1) was also employed where the left-hand side variable was the output of worker 1A or worker 1 (and similarly for 2A and 2, 5A and 5), with all of the explanatory variables being interacted with the dummy variable representing the particular replacement in question. This is referred to as the Interacted Model.

To assess the presence of a Hawthorne effect in the context of these models, Equations 1 and 2 were estimated for each worker including a dummy variable with the value of 1 in each week of experimental change (and 0 otherwise). Sample sizes varied for specification 1 and for the interacted model, depending on the length of time the worker spent in the group, though specification

2 was always estimated on the 159 weeks when all five core group members were present and had been present in the preceding week. The estimated coefficients on these dummy variables are given in Table 4. For specification 1, there is little evidence of a common (Hawthorne) effect in either the Narrow or Broad case; the pattern of signs is mixed with the only significant coefficients suggesting a negative Hawthorne effect, controlling for the other variables. For the interacted model (which only matters for the three workers who were replaced at some point in the five year study), the results are similarly checkered though, again, the only coefficient significantly different from zero at a 5% level is negative. Similarly, when allowance is made for partial adjustment and potential interdependence of the workers' output levels, the dummy variables representing an experimental change are uniformly insignificant. As with the unconditional results of Table 3, there seems to be essentially no evidence of a Hawthorne effect.

Patterns of Residuals

The final diagnostic check we employ is to examine the pattern of residuals from equations (1) and (2) when estimated excluding the experimental change dummy variables. The presence of a marked pattern of such residuals in periods following a change could suggest some type of Hawthorne effect, perhaps of a form too subtle to be adequately captured by a single contemporaneous dummy variable. Accordingly, the six models of

Table 4 (excluding the interacted specification) were reestimated and the residuals plotted. Figures 3-8 illustrate these results where, for each number of weeks after an experimental change, each person's residual is averaged. In addition, for each such week, the average is computed across individuals (weighted by the number of such weeks that the individual was in the sample). The circles in these figures are the individual mean residuals while the triangles, joined by a line, are the (weighted) mean of these individual mean residuals.

Figures 3 and 4 show the results for the simple specification 1. Under both the narrow and the broad definition, the pattern seems to be of slightly negative residuals shortly after a change, offset by larger positive effects beyond 15 weeks after the experimental change. Of course, these latter effects are based on relatively small samples (since most experimental changes were followed by another change within 15 weeks) and are not significant. In addition, it seems hard to construct a convincing story for why a Hawthorne effect might take over three months to develop.

The residuals from Figures 5-8, covering the OLS and IV estimates of specification 2 for the Narrow and Broad cases, are similarly flat when averaged by week after the occurrence of an experimental change. In this case, the point estimates seem to fluctuate very closely around zero, with no clear departure even many weeks after an experimental change when sample sizes become quite small.

Conclusion

This paper has examined the evidence for a Hawthorne effect based on the five years of quantitative data on individual output levels available from the original Hawthorne studies. In contrast to the conventional wisdom in much research and teaching, essentially no evidence was found of Hawthorne effects, neither unconditionally nor with allowance for direct effects of the experimental variables themselves. This result seemed robust across a wide variety of specifications, alternative samples, and two definitions of experimental change.

The one remaining interpretation of a Hawthorne effect that could survive the present investigation is that first discussed above, namely that the whole 270 week period of study was but one experiment, and that all of the various changes introduced at the start of the study and maintained throughout it were one experimental change. Since we have no data on a control group, this interpretation means that there is in essence only one data point and, clearly, the original Hawthorne data are not adequate to the task of assessing this view. While this point is important, it is also important to note that established interpretations of the Hawthorne studies cited above never employ this variant of the Hawthorne effect. Indeed, a question raised by the present findings is why in fact the Hawthorne evidence for Hawthorne effects has had such wide currency for so many years.

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Footnotes

[1]See also Adair, Sharpe and Huynh (1989b) for further discussion of placebo, Hawthorne and other controls in experimental research.

[2]Roethlisberger and Dickson (1939) cite the case of two "capable and willing operators" who maintained their productive efficiency even when the amount of light was cut to 0.06 of a foot-candle, "an amount of light approximately equal to that on an ordinary moonlight night" (p.17).

[3]There were actually eight women in the study overall, counting three replacement workers, labelled 1A, 2A and 5A. The weeks when they replaced workers 1, 2 and 5 are detailed in Table 1.

[4]The data set employed in this study is based on pioneering work by Franke and Kaul (1978) and Franke (1979, 1980), extended using data from Whitehead (1938) by Jones (1990). It is available on request on supply of an IBM-formatted diskette.

[5]Jones (1990) gives further detailed information about the Relay Assembly Test Room and the variables constructed for this research.

Table 1

Main Experimental Changes in Hawthorne Relay Assembly Test Room

Period	Weeks	Change
1	1- 3	(still in main plant)
2	4- 7	Move to test room*; ↑ in VRest (from 0)
3	8- 15	Small group Incentive introduced, VRest ↑
4	16- 20	Sched Stop, Sched Rest Time (2×5 mins); VRest ↓
5	21- 24	Sched Time ↑ (2×10mins), VRest ↕
6	25- 28	Sched Stop ↑ Sched Time ↑ (6×5mins), VRest ↓
7	29- 39	VRest ↑, Sched Stop ↓, Sched Time ↓ (15 & 10min)
8	40- 46	Raw materials problems, VRest ↓; 1 & 2 replace 1A & 2A
9	47- 50	VRest ↓ (mostly), shorter working day (1/2 hour less)
10	51- 62	VRest ↑, return to full working day
11	63- 71	VRest ↕, 5 day week (from 5.5)
12	72- 83	Days/week ↑, Sched Stop & Time ↓ (to 0), VRest ↑
13	84-114	Sched Stop & Time ↑ (to 2, 25), VRest ↓
14	115-123	VRest ↓ (mostly); 5A replaces 5 in week 120
15	124-154	VRest ↓ (slightly)
16	155-158	Raw materials problems end, VRest ↕
17	159-183	Days/week ↓, VRest ↕; 5 returns to replace 5A
18	184-198	Days/week ↓, VRest ↑ (slightly)
19	199-210	VRest ↕

20	211-238	Vrest ↓
21	239-241	Days/week ↓, VRest ↓
22	242-250	VRest ↓
23	251-253	VRest ↓ (to 0), Days/week ↓
24	254-270	Sched Stop & Time ↓ (to 0), Days/week ↓; 5A replaces 5

Notes. *Changes relative to regular department include: smaller room; more uniform lighting; fans for use in summer; one layout operator for 5 women, not for 6-7; new chute mechanism; fewer relay types to assemble (in general); new repairs procedure; test room observer "took over some of the supervisory functions" (Roethlisberger & Dickson 1939, p.39); periodic physical examinations; and women were allowed to talk more freely.

Table 2

Summary Statistics for all Variables

Variable	N	Mean	Std. dev.	Minimum	Maximum
Output 1	218	69.5	4.5	60.1	80.8
Output 2	216	73.0	5.0	59.9	82.4
Output 3	256	63.2	4.6	43.7	72.9
Output 4	256	67.2	7.1	48.1	82.4
Output 5	204	59.8	5.7	47.7	69.8
Output 1a	39	51.6	3.1	44.4	56.4
Output 2a	38	52.0	3.2	45.6	56.8
Output 5a	52	55.7	5.4	43.4	64.2
Days/week	257	5.0	.6	3	5.5
Unemp. rate	270	8.8	6.6	3.2	23.6
Repair time 1	231	27.7	15.0	0	59.9
Repair time 2	231	22.5	11.1	0	42.7
Repair time 3	270	19.6	11.8	0	40.7
Repair time 4	270	11.6	7.9	0	30
Repair time 5	213	18.1	12.6	0	69
Repair time 1a	39	20.5	11.6	0	38
Repair time 2a	39	18.9	12.1	0	37.4
Repair time 5a	57	40.5	27.6	0	69
Vol. rest 1	231	4.5	3.3	0	15
Vol. rest 2	231	6.7	4.1	0	20.6

Vol. rest 3	270	6.1	3.3	0	13
Vol. rest 4	270	7.4	4.1	0	16.5
Vol. rest 5	213	5.8	2.0	0	8.9
Vol. rest 1a	39	9.2	4.6	0	13.7
Vol. rest 2a	39	8.2	5.6	0	17
Vol. rest 5a	57	3.3	2.1	0	6.4
Raw mats.	270	.1	.4	0	1
Small group pay	270	1.0	.2	0	1
No rep. time rpt.	270	.1	.4	0	1
No vol. rest rpt.	270	.1	.3	0	1
No sch. rest rpt.	270	.1	.2	0	1
Sched. rest stops	270	1.7	.9	0	6
Sched. rest time	270	20.6	9.4	0	30
1A/2A replacement	270	.9	.4	0	1
5A replacement	270	.2	.4	0	1
Seating change	270	.2	.4	0	1
No medical rpts.	270	.4	.5	0	1
Worker 1 ill	270	.1	.3	0	1
Worker 2 ill	270	.1	.2	0	1
Worker 3 ill	270	.1	.2	0	1
Worker 4 ill	270	.0	.2	0	1
Worker 5 ill	270	.0	.1	0	1
Heat wave	270	.0	.2	0	1
Cold wave	270	.0	.2	0	1
Narrow exp. change	270	.1	.3	0	1
Broad exp. change	270	.3	.5	0	1

Table 3

Mean Output Levels in Periods around Experimental Changes

	q1	q2	q3	q4	q5	q1A	q2A	q5A
				Overall				
	69.5	73.0	63.2	67.2	59.8	51.6	52.0	55.7
	218	216	256	256	204	39	38	52
				Narrow Definition (Δ)				
Δ(-1)	68.9	71.6	61.0	63.4	57.6	51.2	50.9	56.8
	17	16	24	24	21	8	8	4
Δ(0)	69.6	71.3	61.3	63.9	58.4	52.3	53.7	56.1
	17	16	24	24	21	7	6	7
Δ(1)	70.1	72.6	62.3	65.0	58.7	51.4	52.0	57.5
	17	17	24	24	19	7	7	4
Δ(2)	69.4	72.0	61.5	64.5	58.3	52.0	51.2	55.7
	17	16	24	24	20	7	7	4
Δ(3)	70.2	72.3	63.0	65.8	58.5	51.3	51.6	56.2
	17	16	23	24	20	7	7	4
Δ(4)	70.2	73.3	62.3	65.6	58.9	52.1	53.2	55.6
	16	16	22	22	18	6	6	4
				Broad Definition (Δ*)				
Δ*(-1)	69.7	72.9	62.6	65.8	58.8	51.4	51.5	56.5
	60	58	79	79	61	19	19	18
Δ*(0)	69.4	72.6	62.5	66.2	58.7	51.8	52.0	57.0

	64	63	82	82	63	18	17	18
Δ*(1)	69.7	73.2	62.5	66.6	59.0	51.0	51.7	57.1
	64	64	82	81	63	18	18	18
Δ*(2)	69.8	73.5	62.5	66.8	59.1	51.1	51.2	56.7
	63	62	79	79	61	17	17	19
Δ*(3)	69.9	73.4	63.1	66.7	59.1	51.2	50.9	57.0
	67	65	83	84	64	17	17	20
Δ*(4).	69.9	73.4	62.9	66.7	59.1	52.1	52.4	57.5
	68	67	84	84	63	16	15	21

Note: Δ(n) denotes the week n periods after a Narrow experimental change, Δ*(n) analogously for the Broad definition. The second entry in each cell is the sample size.

Table 4

Estimates of Experimental Change Effects

	q1	q2	q3	q4	q5
		Narrow Definition			
OLS Specification 1	.93	-.74	-.09	-.72	.46
	(.73)	(.83)	(.49)	(.77)	(.58)
OLS Interacted Model	1.00+	.02	---	---	.38
	(.60)	(.70)			(.62)
OLS Specification 2	.52	-.95+	.18	.56	.21
	(.59)	(.53)	(.51)	(.77)	(.56)
IV Specification 2	.51	-.89	.29	.51	.59
	(.63)	(.56)	(.58)	(.81)	(.63)
		Broad Definition			
OLS Specification 1	.14	-.94+	-.09	-.32	-.91*
	(.47)	(.52)	(.34)	(.53)	(.40)
OLS Interacted Model	.28	-.65	---	---	-.81*
	(.42)	(.47)			(.42)
OLS Specification 2	.43	-.49	.09	.19	-.50
	(.39)	(.35)	(.34)	(.53)	(.37)
IV Specification 2	.37	-.40	.06	.14	-.36
	(.41)	(.37)	(.36)	(.52)	(.39)

Notes: Control variables for specification 1 for worker i (i=1,...,5) were Repair time of i, vol. rest time of i, a dummy variable indicating if worker i was ill (but worked in the week in question), days per week, a dummy for raw material problems, scheduled rest time, scheduled rest stops, a dummy for the seating change, dummy variables for a heat wave or a cold wave (as reported for the week by the Chicago Tribune), and dummy variables for the absence of data on scheduled rest stops and for the absence of medical reports. In addition, replacement worker dummies were included for 5/5A (for i=1,...,4) and for 1/1A and 2/2A (for 1=3,4,5). Sample sizes for the OLS specification 1 were, respectively, 218, 216, 256, 256 and 204. For the interacted model, these controls were all interacted with the replacement dummy variable, as well as entering the equation themselves. Sample sizes were 257, 254 and 226 respectively. For specification 2, additional regressors were the lagged dependent variable and the contemporaneous output levels of the other four workers. In this case, all estimates are for the consistent core sample of 159 weeks as detailed in the text. Coefficients denoted * and + are significantly different from zero at the 5 percent and 10 percent levels, respectively.

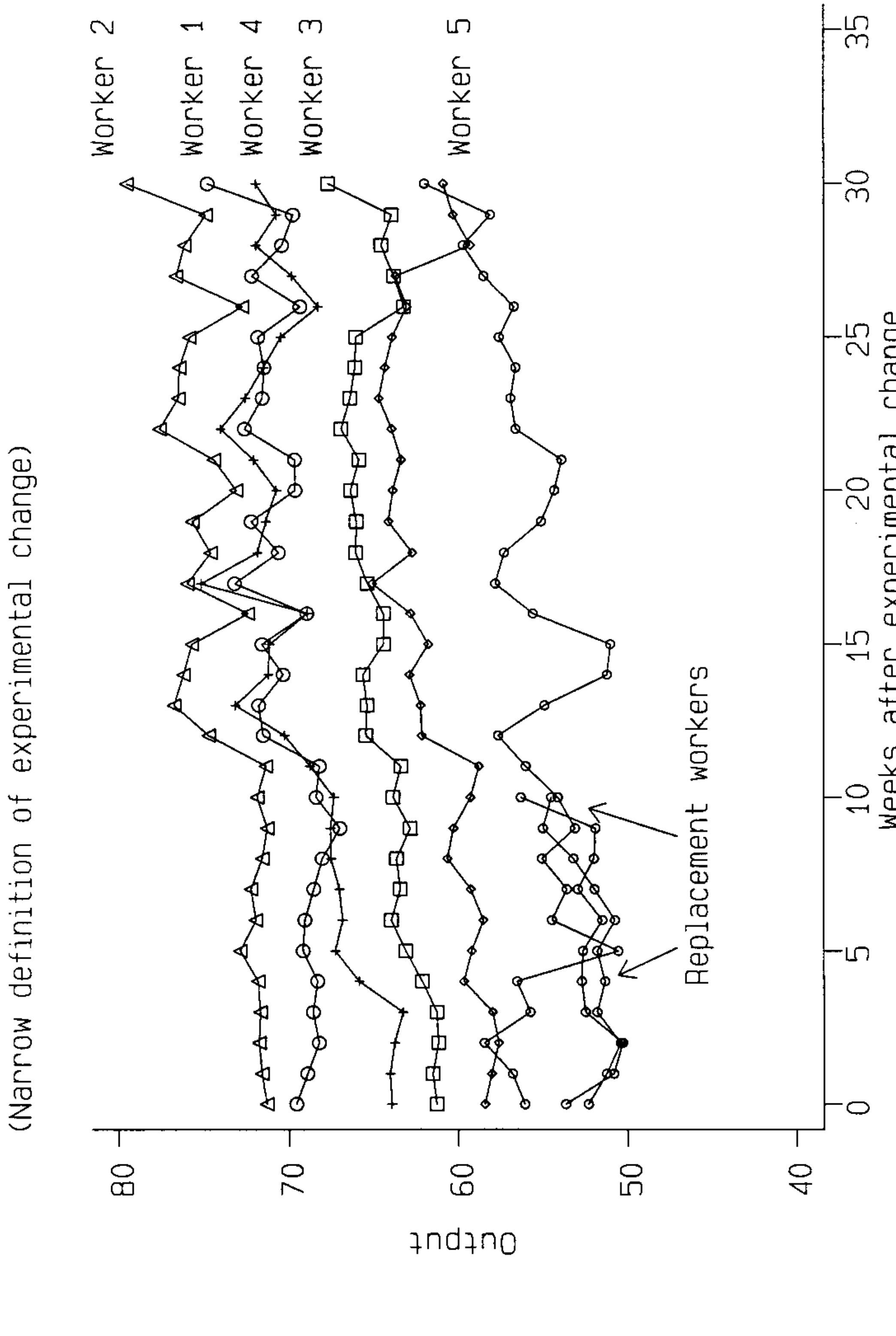

Figure 1: Mean output levels

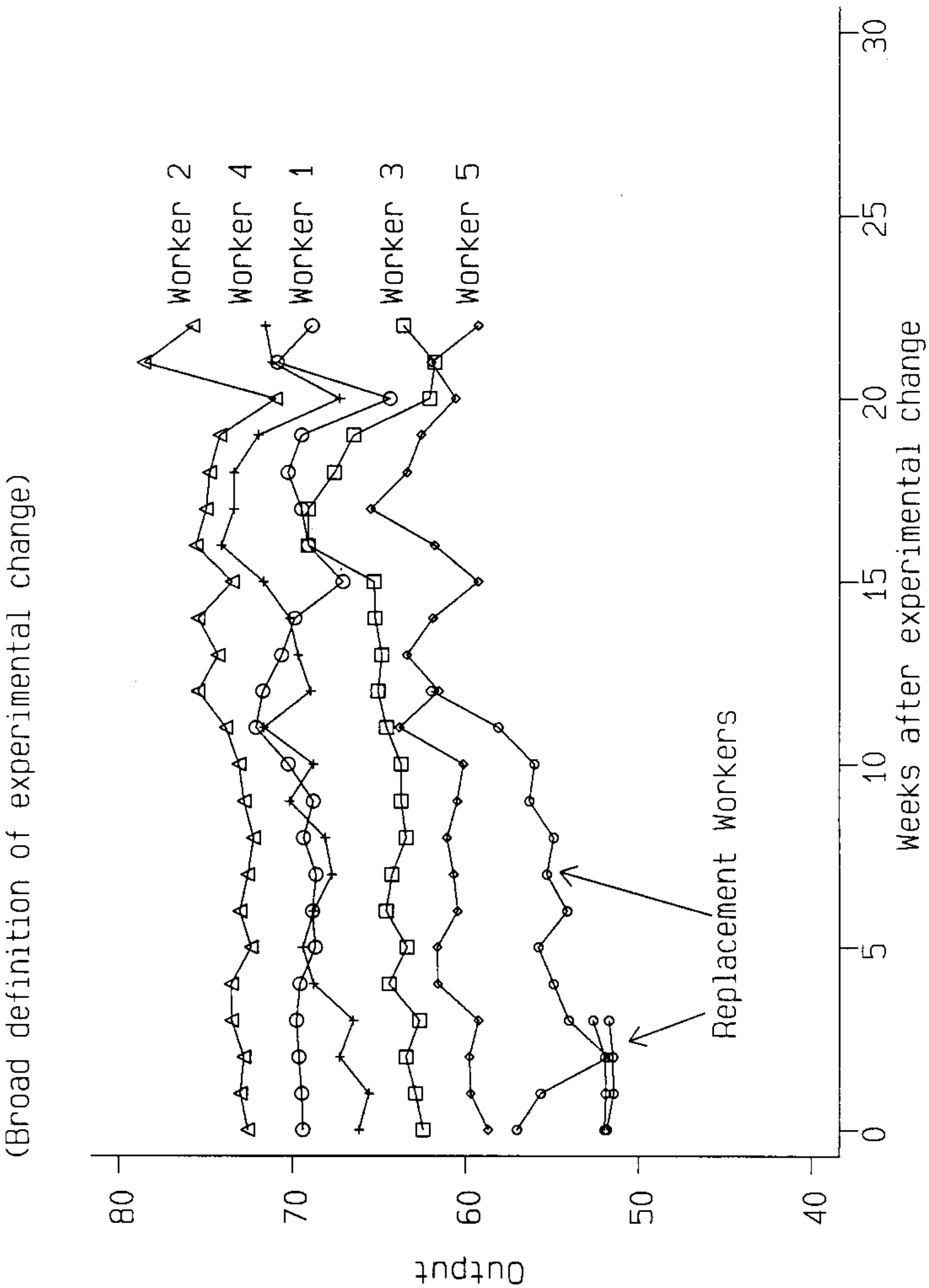

Figure 2: Mean output levels

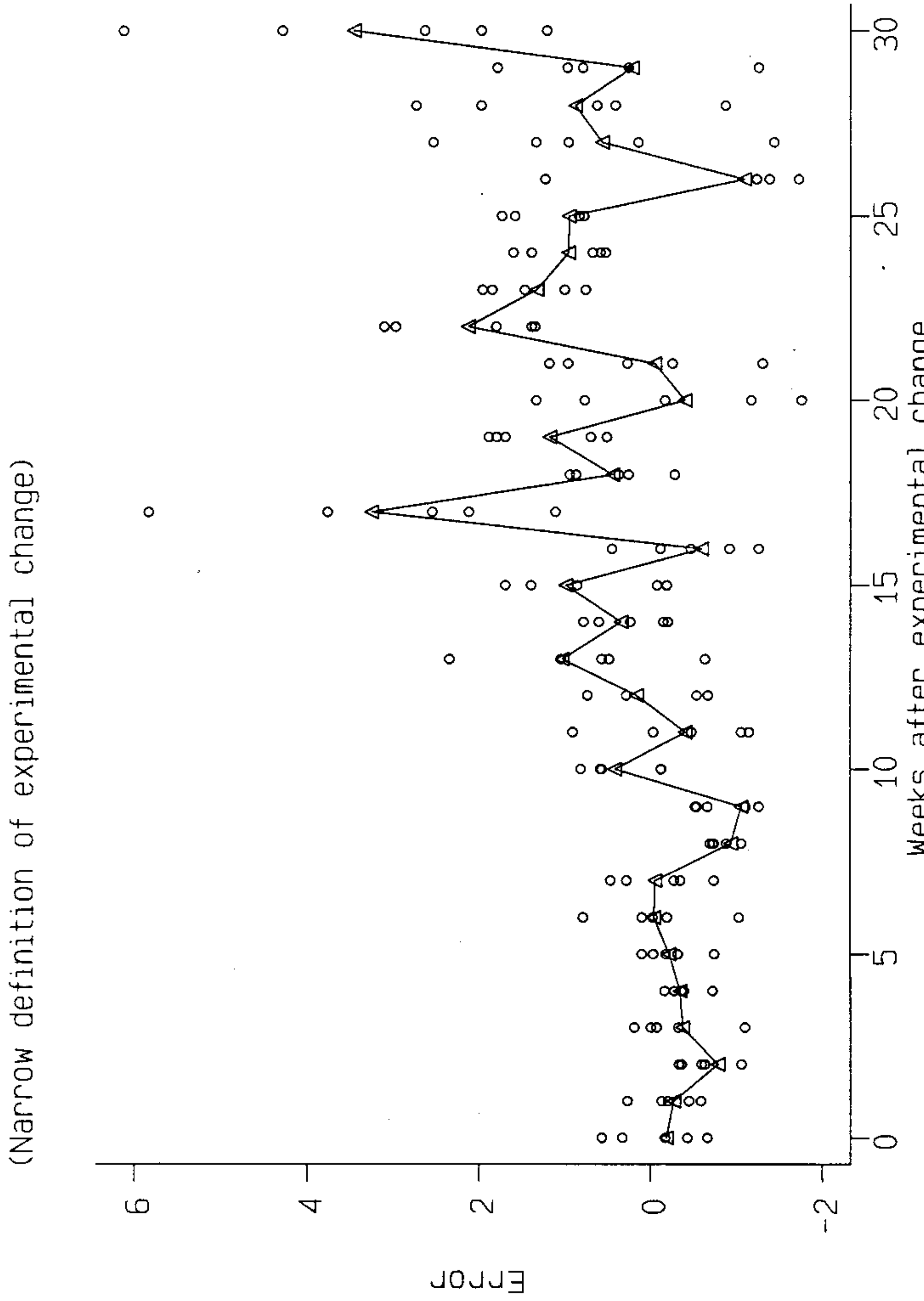

Figure 3: Residuals from OLS specification 1

(Broad definition of experimental change)

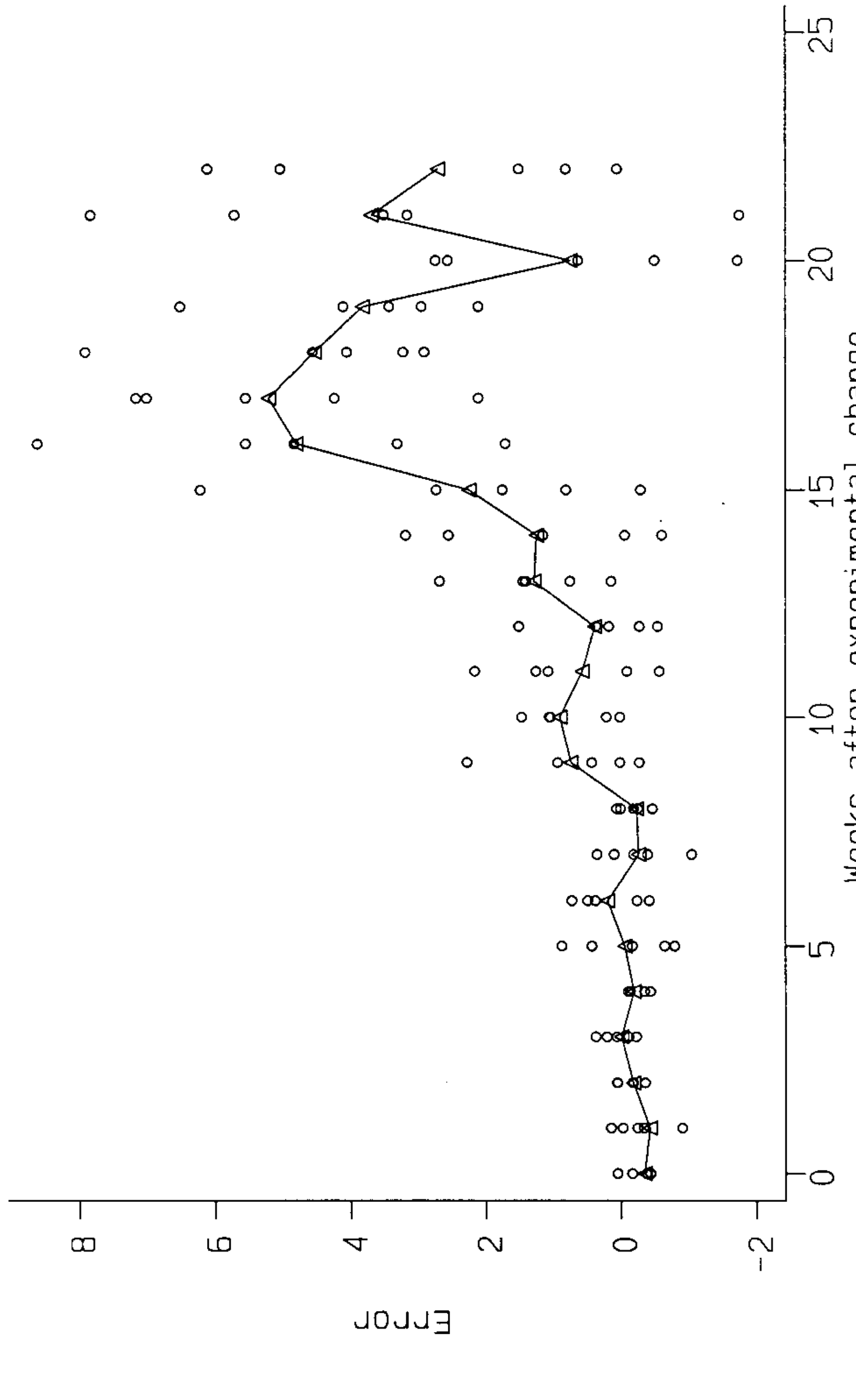

Figure 4: Residuals from OLS specification 1

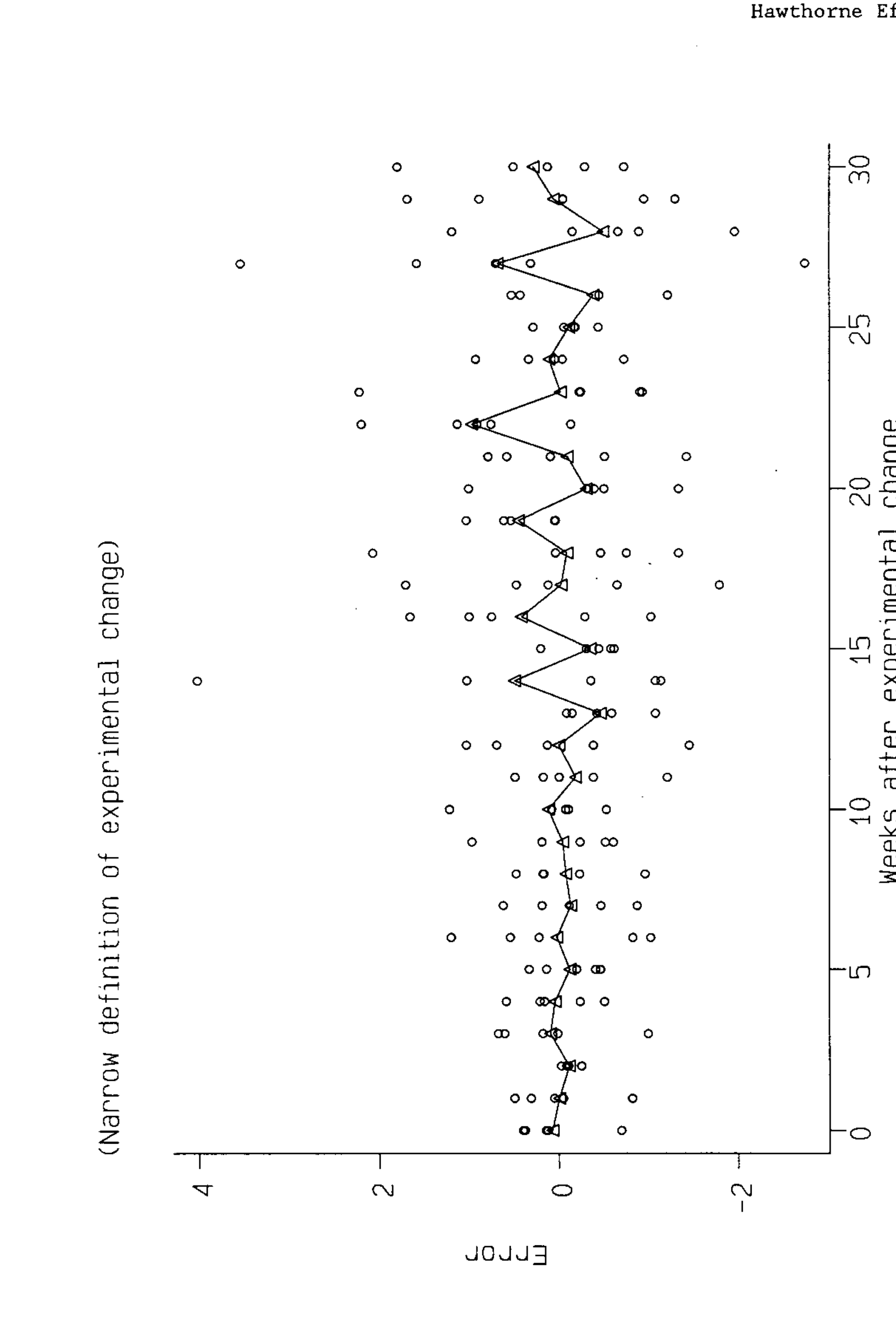

Figure 5: Residuals from OLS specification 2

(Narrow definition of experimental change)

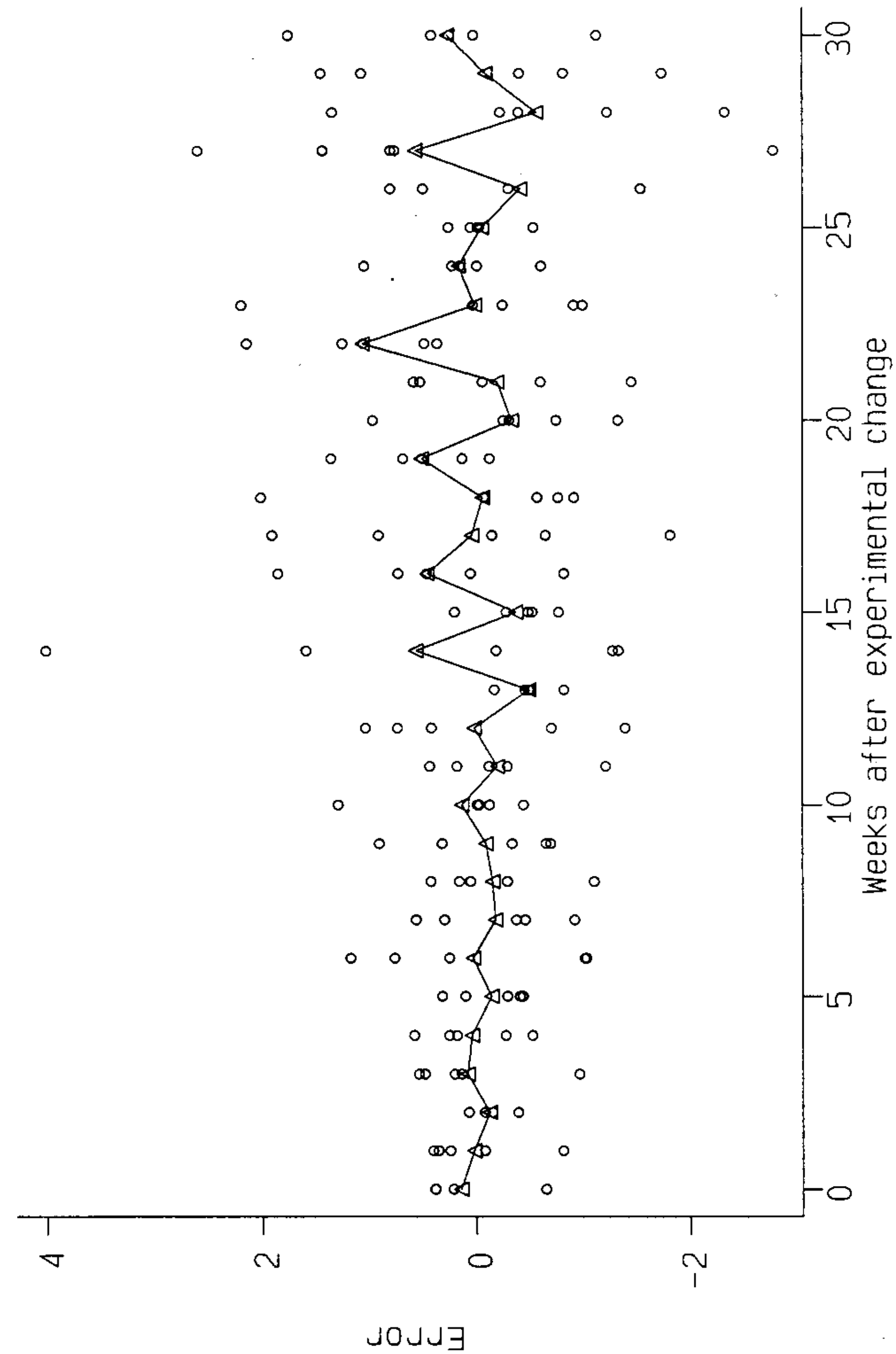

Figure 6: Residuals from IV specification 2

(Broad definition of experimental change)

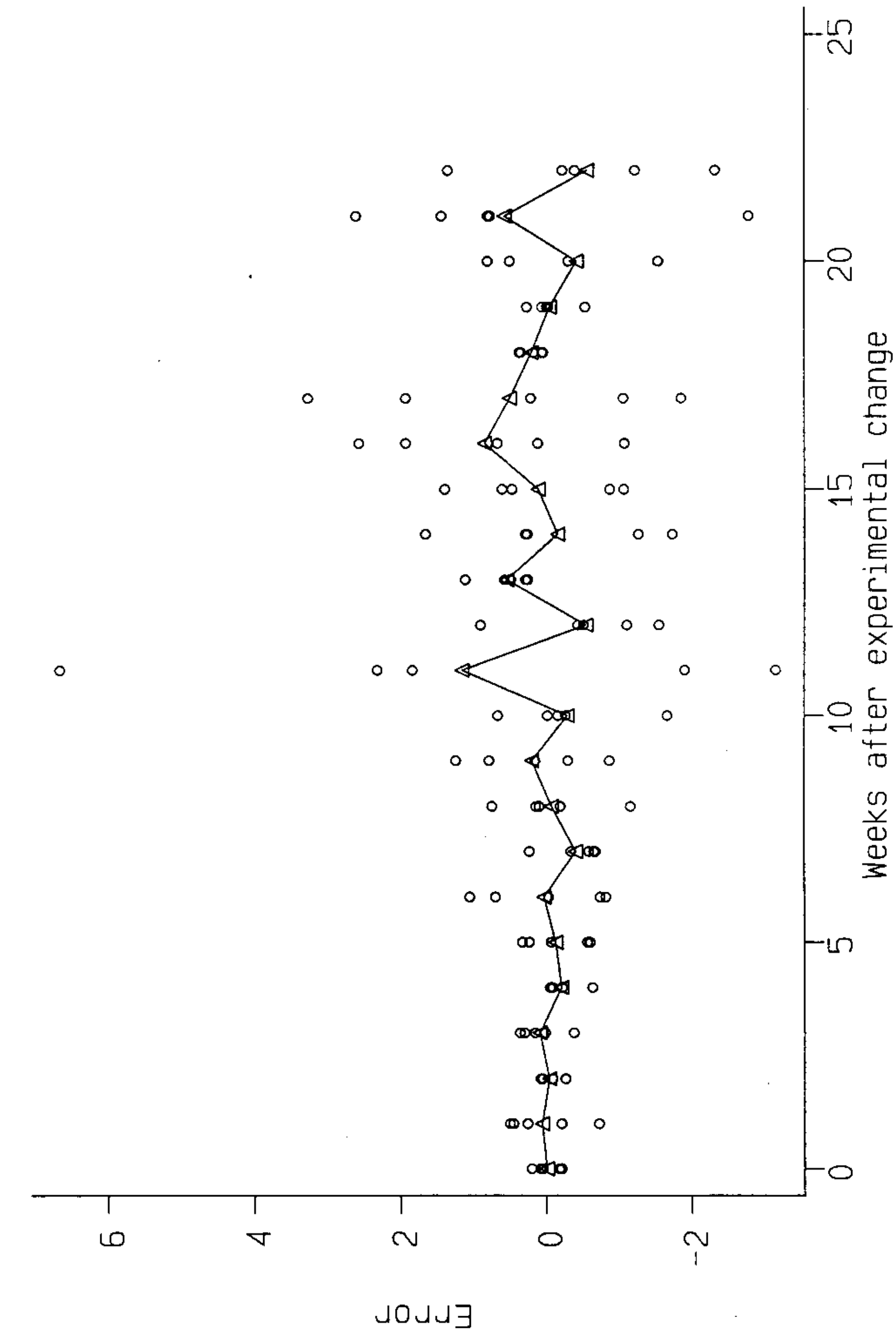

Figure 8: Residuals from IV specification 2

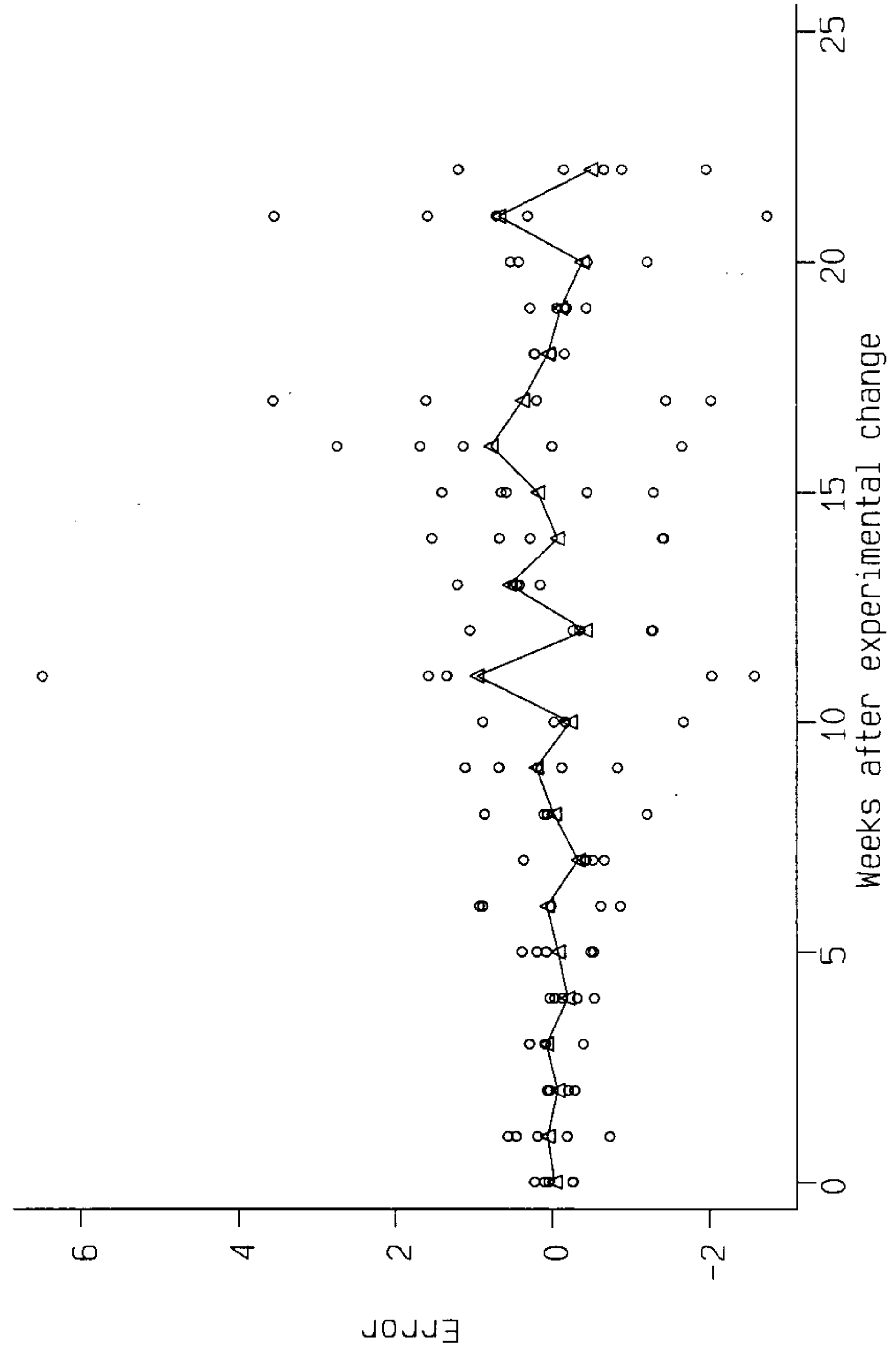

Figure 7: Residuals from OLS specification 2

(Broad definition of experimental change)

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