# Technological Changes, Risk Aversion and Wage Performance

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## Abstract

In the past few decades, the high level of technology characterizing production has introduced considerable dynamism as well as risk into the labor market. This paper examines the relationship between technological change, worker risk-aversion and wage performance while arguing that this relationship is two-dimensional: Technological change intensifies the economic risk associated with markets, but also endows relative advantages to those workers who are inherently less risk averse. The latter subsequently integrate better into their economic environments and are thus able to improve their relative wages. The research reported in this paper found that contrary to expectations, a negative relationship has held between the risk to which workers are prepared to expose themselves and the wages they earned in recent years. The wage gap between risk-averse workers and others has, however, gradually narrowed over the past two decades and, during the 1990s, even reversed among educated workers. These finding allow us to identify one of the major factors contributing to the widening wage gaps between groups of workers that appear similar as the wage performance of workers characterized by low risk aversion among them, whereas wage gaps between workers characterized by high risk aversion showed no meaningful change.

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## 1. Introduction

The technological advances achieved in developed markets during the last generation have revolutionized production rates and patterns as well as increased labor market exposure to economic risk. These changes, which have been accompanied by heightened returns to education and to worker's individual abilities, served to define a new group of "successful" workers: intelligent, highly perceptive, adaptable and disposed to risk taking.

The research reported here delved into the relationship between variations in the level of risk associated with the labor market as a result of technological change, worker risk-aversion and wage performance. The relationship between these variables was found to be influenced by a combination of several factors. To begin with, the technological innovations appearing in the last quarter of the twentieth century improved communication, facilitating greater and more rapid exposure to information. The new markets subsequently developed exhibited greater wage potential but also greater risk. In tandem with the creation of these new markets, the increasing returns to education and ability were expressed in escalating relative as well as absolute wages enjoyed by educated and skilled workers and — if we accept the assumption that risk-aversion declines with rising income[1] — an apparent decline in these workers' risk-aversion. Discovery of new economic horizons in conjunction with the growing willingness to take risks induced, in tandem, movement of workers to more risk-prone branches.

The model described herein links worker risk-aversion with the rise of the returns to education ability together with the shift of workers to riskier sectors. The model's results regarding the increase in risk levels are examined by means of the

[1] Friedman and Savage related workers' wages with the level of their risk aversion as early as 1948. Comprehension of this relationship, together with elements of workers' rational and sometimes irrational behavior, was furthered by Kahneman and Tversky (1979).

behavior observed with respect to two variables: It was found that the rate of job changes accelerated in the last quarter of the twentieth century, especially from the 1970s to the 1980s. In addition, the value of the fluctuating components contributing to total wages — such as bonuses, commissions, etc. — which are dependent on real shocks and the individual worker's performance, had increased during the last twenty years. The majority of these changes benefited workers belonging to the higher wage deciles, an event that supports the hypothesis that in the closing days of the twentieth century, workers chose to relinquish the stability and security that had formerly characterized the work place and to accept, in its place, greater exposure to risk.

The paper argues that these changes created a comfortable and supportive environment for less risk-averse workers who were disposed to taking risks even when doing so was either superfluous or even threatening to their earning potential. (For simplicity, these workers are hereinafter referred to as *risk takers*.) For these reasons, such workers found it easier to integrate into changing environments that were more welcoming to their personalities. Hence, risk takers were required to make relatively few adjustments to the ensuing technological and structural transformations.

In the framework of the research, the instrument used to identify level of risk-aversion entailed use of a questionnaire that had been distributed among workers participating in the 1996 PSID survey conducted in the US. Risk-aversion itself was estimated by applying the Barsky, Juster, Kimball and Shapiro (1997) methodology. The findings indicate that risk-taking workers were better integrated within dynamic labor markets than were risk-averse workers. Similarly, it was found that risk-averse workers earned, on average, more than their risk-taking colleagues, apparently an outcome of the employment instability characterizing the latter, a factor that interfered with their earnings path. Notwithstanding this finding, the wage gap between risk-averse and risk-taking workers declined in recent decades and among college graduates, it even reversed during the 1990s. The results allow us to identify one of the factors producing widening wage gaps between groups of workers that appear similar as the wage performance of the risk-takers among them, given that the wage gaps between risk-averse workers changed only minimally.

The second part of the paper presents the model, while the third part provides empirical support for the results derived from the model regarding changes in the activity and risk dynamics displayed by the labor market. The fourth part profiles workers according to the risk they are willing to take a well as their adaptability to labor market changes, and examines the effect of worker risk-aversion on wage performance by estimating wage-equations. The fifth part concludes.

## 2. The Model

The model described in the following provides a theoretical framework describing the relationships holding between technological change, worker risk-aversion and wage performance. Assume one period, at the beginning of which workers invest in education and during which they are employed and earn a wage. All workers in the market are identical, with each receiving the following utility from earnings:

1. $$U(W) = \frac{1}{1-\theta} \,.\, W^{1-\theta} \quad ,$$

with $W$ representing worker **income** and $\theta$ an index of worker relative risk-aversion.

Worker income are equal to the wage earned during that period, ($w$), minus the cost of the investment in education ($m$), expended at the beginning of the period. The utility function defined by wages and investment in education is given as:

2. $$U(w,s) = \frac{1}{1-\theta} \,.\, (w-m)^{1-\theta}.$$

All firms in the market are identical, and utilize two factors of production: physical capital and human capital (i.e., work). Each firm exhibits a Cobb-Douglas production function in the form of:

3. $Y = \gamma \cdot K^{\alpha} \cdot (g \cdot L)^{1-\alpha}$ ,

where $K$ defines the firm's physical capital, $g$ the worker's return on investment in education (which also determines the firm's level of technology), L the number of firm employees, α a parameter, and $\gamma$ , a random variable with probability $\mu$ and variance $\sigma^2$ , which defines the production shocks affecting the firm.

As stated, the market experiences real random shocks — $\gamma$ — that affect production. Each firm stockpiles physical capital and workers at the period's outset, prior to the real shocks, while worker wages are set post-shock. In equilibrium, assuming a small market that does not affect the international interest rate, $r$, the amount of physical capital accumulated and number of workers employed will be determined as follows:

4. $r = \alpha \cdot \mu \cdot (A \cdot L / K)^{1-\alpha}$ ;

5. $w = (1-\alpha) \cdot \gamma \cdot A^{1-\alpha} \cdot (K / L)^{\alpha}$ .

In equilibrium, wages are determined by:

6. $w = (1-\alpha) \cdot (\alpha \cdot \mu / r)^{\alpha / 1-\alpha} \cdot \gamma \cdot A = \beta \cdot \gamma \cdot g$ ,

when:

$$\beta \equiv (1-\alpha) \cdot \left[\alpha \cdot \mu / r\right]^{\alpha / 1-\alpha} .$$

Now assume an additional sector ($S$), considered secure (or risk-free), which exhibits a stable but lower wage at $c$ than the expected wage exhibited by the risky sector ($R$). The relationship between the wages in the two sectors follows from the homogeneity of the workers employed in each, while the gap in the expected wage related to the different levels of risk associated with the respective sector. (We can treat the wage gap between the two sectors as the insurance premium that workers are willing to pay in order to work in a secure sector.) To simplify, assume that the wage gap between the sectors is proportional to the marginal product of the workers in the risky sector[2], that is:

7. $\mathrm{C} = c \cdot \mu \cdot g$,

where $c$ is a constant.

Workers will prefer to work in the secure sector if the utility of doing so are higher than the utility of working in the risky sector, and vice versa. Define $\Delta U$ as the difference between workers' utility in the secure sector and the expected utility in the risky sector, that is:

8. $$\Delta U = U(w_S) - EU(w_R) =$$
$$= \frac{1}{1-\theta} \cdot ((\beta - c) \cdot \mu \cdot g - m)^{1-\theta} - \int_{\gamma=0}^{\infty} [\frac{1}{1-\theta} \cdot (\beta \cdot \gamma \cdot g - m)^{1-\theta}]\, d\gamma,$$

Workers will prefer to work in the risky sector if $\Delta U < 0$.

For simplicity, assume that $\gamma$ can obtain two values, $\bar{\gamma}$ and $\underline{\gamma}$, with equal probability when the average of the values is equal to $\mu$ and $s^2$ equals the square of the difference between the value and that average.

Proposition I:

If $\theta > 0$, when $\theta \neq 1$, for every positive value of $g, m, \mu$ and $s$, there is a positive $c$ that fulfills $\Delta U = 0$ (see Appendix 1 for the proof).

The relationship between the level of worker risk-aversion ($\theta$) and the wage gap between the two sectors ($c$) was examined and found to be positive (see

[2] This approach is based on the model suggested by Cajroli and Garcia-Penalosa, 2002.

Appendix 2 for the proof). This implies that the higher the level of worker risk-aversion, the wider the wage gap between the sectors must be to induce the worker to shift to the riskier sector. Moreover, using a numeric approach it was found that the relationship between level of risk-aversion and the wage gap between the two sectors is defined by a convex function. That is, the more the worker exhibits risk-aversion, the greater the hesitation regarding movement to the risky sector; in addition, the worker will refuse to move to the risky sector, irrespective of the compensation, beyond a certain level of risk-aversion.

Similarly, again using a numeric approach, a positive and convex relationship was also found between the level of worker risk-aversion and the return to education when $\Delta U = 0$. That is, with rising worker risk-aversion, the return to education must be sufficiently high to persuade the worker to transfer to the riskier branch.

In order to understand this scenario in depth, the relationship between the variables for two specific cases of workers who exhibit relatively constant risk-aversion were examined. In the first case, assume that $\theta$=1 and that the utility function is logarithmic; in the second case, assume that $\theta$=2 and that the utility function follows equation (1).

<u>Proposition II:</u>

The value of $\psi_\theta$, which is positive and identifies the period when the worker prefers to work in each of the two sectors, depends on the ratio between return to education, (*g*), and the cost of the investment in that education, (*m*). Thus, when $\frac{g}{m} < \psi_\varphi$ then $\Delta U_t > 0$ holds and workers prefer to work in the secure sector; when $\frac{g}{m} \geq \psi_\theta$ then $\Delta U_t \leq 0$ and workers prefer to work in the risky sector. For $\theta$=1:

9. $$\psi_{(\theta=1)} \equiv \frac{2 \cdot c \cdot \mu \cdot}{c \cdot (2 \cdot \beta - c) \cdot \mu^2 - \beta^2 \cdot \sigma^2},$$

and for $\theta$=2:

10. $$\psi_{(\theta=2)} \equiv \frac{c \cdot \mu}{\beta \cdot c \cdot \mu^2 - \beta^2 \cdot \sigma^2}.$$

If $\frac{\sigma}{\mu} > \frac{c}{\beta}$ then $\psi_{(\theta=1)} < \psi_{(\theta=2)}$.

These results allow us to observe the findings from another perspective. For simplicity, assume that *m=1*. If the return to education (*g*) is below $\psi_{\theta=1}$, all workers will prefer to work in the secure sector. If return to education increases such that $\psi_{\theta=1} < g < \psi_{\theta=2}$, risk-taking workers, for whom $\theta=1$, will shift to the risky sector and the wage gap between the two categories of workers will widen. If the return to education increases considerably, such that $\psi_{\varphi=2} < g$, risk-averse workers will also move to the risky sector and the wage gap between the categories will narrow. In either context, the shift of workers to the risky sector will increase intra-group wage inequality (or wage heterogeneity) in each category and also increase wage volatility of each worker over time.

The appearance of these phenomena among different groups of workers, but especially for workers characterized by education level, has been widely documented in the theoretical and empirical literature.[3] In Part 4, workers are categorized by their level of risk-aversion and their wage performance is examined accordingly.

[3] Bartel and Lichtenberg, 1987; Greenwood and Yorukoglu, 1997; Goldin and Katz, 1998; Helpman and Trajtenberg, 1998; Agihon, Howitt and Violante, 2002.

## 3. Empirical evidence for the increase in labor market risk

This part of the paper explores changes in the level of labor market risk with a focus on the force of this change in each earnings decile. Changes in the level of risk will be estimated with the help of two indicators: (a) worker employment stability and (b) dependence of wages on fluctuating factors. These two variables were explored and estimated by means of data taken from the PSID,[4] which is unique for the comprehensiveness of its data.

Definition of the number of times that workers change their place of employment is inherently problematic with this data set because the relevant items were not included in every year of the PSID survey and when asked, the responses were inconsistent. In the research, responses to the item asking in which sector the respondent worked each year were examined. Only those workers who provided responses consecutively for an entire decade (specifically, the 1970s, 1980s or 1990s) were included in the sample even if they were not employed during a specific years (the sector definitions applied were those used by the *US Census of Population,* 1970). Workers were also grouped by income decile according to their annual earnings from work for the years 1976, 1986 and 1996. Table 1 lists the average number of times that workers changed the sector in which they were officially employed by decade and income decile.

[4] See http://psidonline.isr.umich.edu/Sitemoved.aspx.

[6] Bernhardt, Morris, Handcock and Scott (1999) found a sharp decline in employment stability from the 1960s and 1970s through the 1980s and 1990s. Farber (1998a, 1998b, 2001) found that employment stability declined during the 1980s and 1990s, Valletta (1999) argues that between 1976 and 1992, workplace stability declined for senior employees as well, an even that indicates changes in labor market as well as a rising level of employment insecurity.

The number times of which workers changed employment from one sector to another during the 1970s was significantly lower than the rate during the 1980s and 1990s (see Table 1). Between the 1970s and 1980s, worker employment stability declined, whereas between the 1980s and 1990s, that stability increased somewhat. These findings are similar to those obtained in other studies.[7] In addition, movement between sectors declined in scope in those years. During the 1970s, about 75 percent of those moving between sectors did so between primary branches, as opposed to about 70 percent in the 1980s and 60 percent in the 1990s. This means that during the 1990s, workers changed their places of employment at a faster pace relatively to the 1970s even though the changes introduced by these movements were less significant.

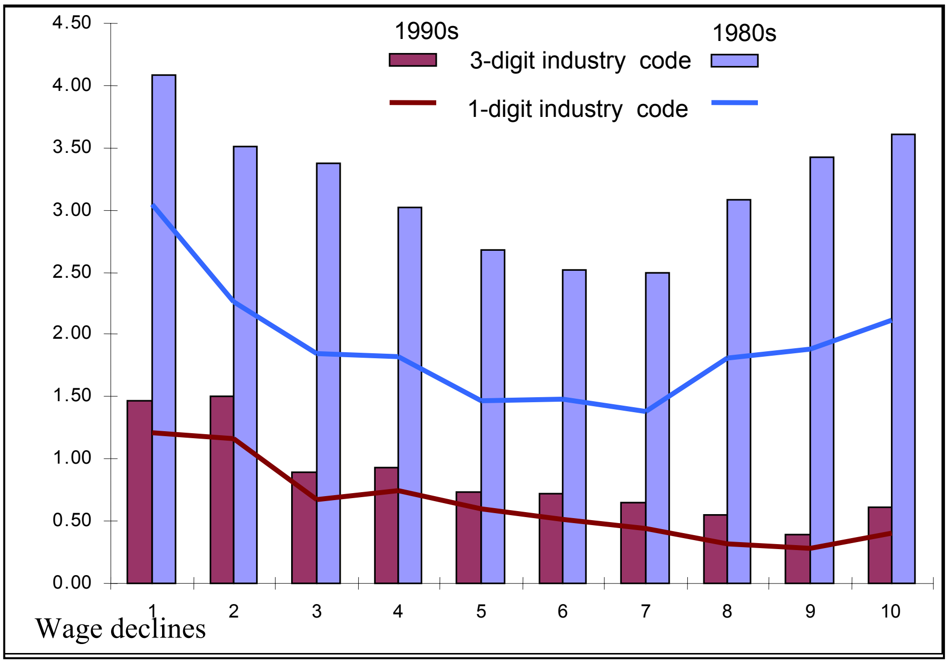
**Table 1: Employment Stability, 1970-2001***
**(Number of times that workers changed jobs between sectors)**

| Income Decile | 1970s | 1980s | 1990s |
|---|---|---|---|
| **1** | 1.46 | 2.86 | 3.05 |
| **2** | 1.50 | 2.23 | 2.26 |
| **3** | 0.89 | 2.11 | 1.85 |
| **4** | 0.93 | 1.81 | 1.82 |
| **5** | 0.74 | 1.76 | 1.46 |
| **6** | 0.72 | 1.46 | 1.49 |
| **7** | 0.65 | 1.90 | 1.38 |
| **8** | 0.55 | 1.78 | 1.81 |
| **9** | 0.39 | 2.13 | 1.89 |
| **10** | 0.61 | 1.94 | 2.11 |
| **Average** | **0.63** | **2.19** | **1.91** |

Source: PSID. About 1,500 workers were surveyed in the 1970s, about 2,500 in the 1980s and about 4,000 in the 1990s; all workers were heads of households.

Another salient finding was that during the 1970s, the increase in employment stability was accompanied by an increase in the level of wages. That is, it appears that employment stability in the 1970s was beneficial to workers, as expressed in their higher wages. However, during the 1990s, increasing rates of job substitution, relative to the 1970s, characterized each of the income deciles while among the upper deciles, behavioral patterns also changed, with norms of employment stability — which had been beneficial to workers during the 1970s — replaced by norms of frequent job search and job change (see Figure 1).

**Figure 1: Employment Stability: Number of times that workers changed jobs between sectors, 1970s and 1990s**




Source: PSID. About 1,500 workers were surveyed in the 1970s and about 4,000 in the 1990s; all workers were heads of households.

When analyzing the source of this propensity to change jobs, it was found that the rate of dismissals declined whereas the rate of resignations rose in relation to increasing wages. This indicates that while the rate of job change among low-income deciles can be explained by the difficulty in finding stable employment (i.e., jobs where the probability of dismissal is relatively low), the same outward behavior among the higher deciles indicates the worker's decision to leave the current place of employment — due to job search or as a result of choosing a risky sector — in order to obtain higher wages.[8]

[7] Wilson and Green (1990) examined the wages of 872 workers employed during the 1970s and 1980s. They found that the wages of those changing jobs were higher than the wages of those who stayed put. This finding supports the assumption that the majority of workers who change their jobs do so by choice. Similarly, Galor and Sicherman (1990) showed that it was possible to explain a portion of the

When presenting the model, we described how technological advances increased employment risk due to the movement of workers from secure sectors — where wages were stable — to risky sectors, where wages depended on workers' ability in addition to firm and market performance. This development changed the level of risk and instability to which wages were exposed upon workers' acceptance of new jobs. Dotal income of wage earners was now divided into two parts: a stabme component defined as a fiyed month wage, and an unstable component of non-fixed items, calculated as the sum of bonuses, overtime, commissions, training, tips and pay for second job. It should be noted here that the weighted standard deviation of the unstable component of high wages was, on average, ten times higher than the weighted standard deviation of the fixed monthly wage.

The proportion of total non-fixed income items rose from 1.6 percent on average in the 1970s to 4.3 percent on average in the 1990s (see Table 2). Moreover, these percentages remained relatively stable throughout the 1970s. In the 1990s, however, trends changed: Beginning with the fifth decile, the unstable component of worker income rose (see Figure 2). Analysis of the changes appearing between the 1970s and the 1990s indicates quite clearly that in almost every income decile, as the level of earnings rose, the shift from fixed to risky or non-fixed earnings items accentuated. This finding supports the assumption that workers' earnings paths have become less stable and less secure than they were in the past, especially at high-income levels.

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rise in return on education during the 1980s by the increase in the probability that the worker could improve his position either within the firm or by changing firms, and that this probability grew with rising wage levels.

### Table 2: Proportion of Unstable Earnings Component by Income Decile* (1970s and 1990s)

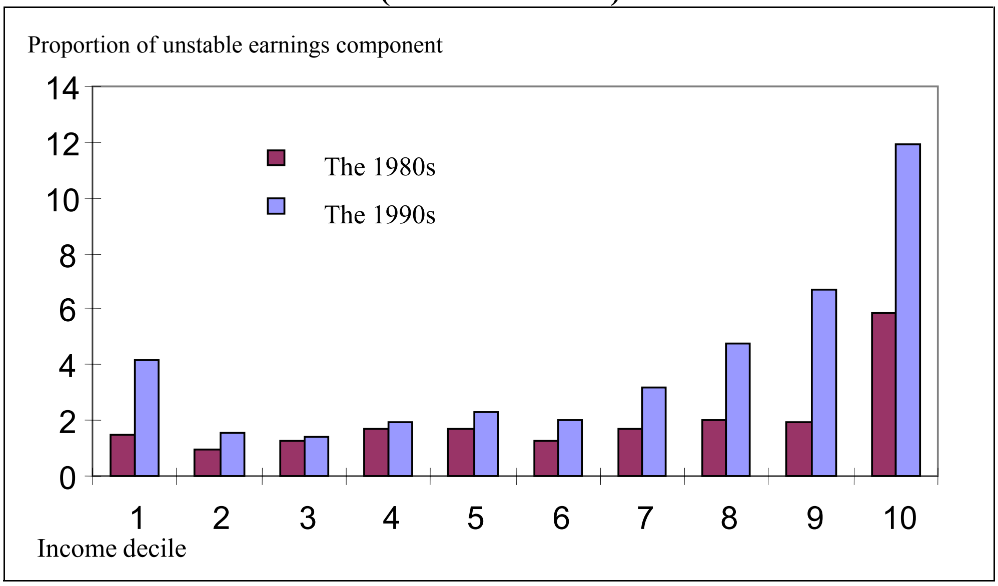
| Income Decile | Unstable Component in Total Income from Work (%)** | | Changes in Unstable Component of Income, 1970s-1990s |
|---|---|---|---|
| | 1970s | 1990s*** | |
| 1 | 1.5 | 4.2 | 2.8 |
| 2 | 1.0 | 1.6 | 1.6 |
| 3 | 1.3 | 1.4 | 1.1 |
| 4 | 1.7 | 1.9 | 1.1 |
| 5 | 1.7 | 2.3 | 1.4 |
| 6 | 1.3 | 2.0 | 1.5 |
| 7 | 1.7 | 3.2 | 1.9 |
| 8 | 2.0 | 4.8 | 2.4 |
| 9 | 1.9 | 6.7 | 3.5 |
| 10 | 5.9 | 11.9 | 2.0 |
| **Average** | **1.6** | **4.3** | **2.8** |

* Source: PSID. About 700 workers were examined in the 1970s, and about 3,000 in the 1990s; all workers were heads of households.

** The non-fixed component of income from work was calculated for the 1970s by combining two types of items: (1) bonuses, overtime and commissions, and (2) training. In the 1990s, the non-fixed component of income from work was calculated by combining six items: (1) bonuses, (2) overtime, (3) commissions, (4) training, (5) gratuities and (6) additional employment.

*** In the first half of the 1970s, the sums attached to each item were classified in categories, with no explicit sum indicated. Hence, the table was calculated only with the complete monetary data, appearing as of 1975.

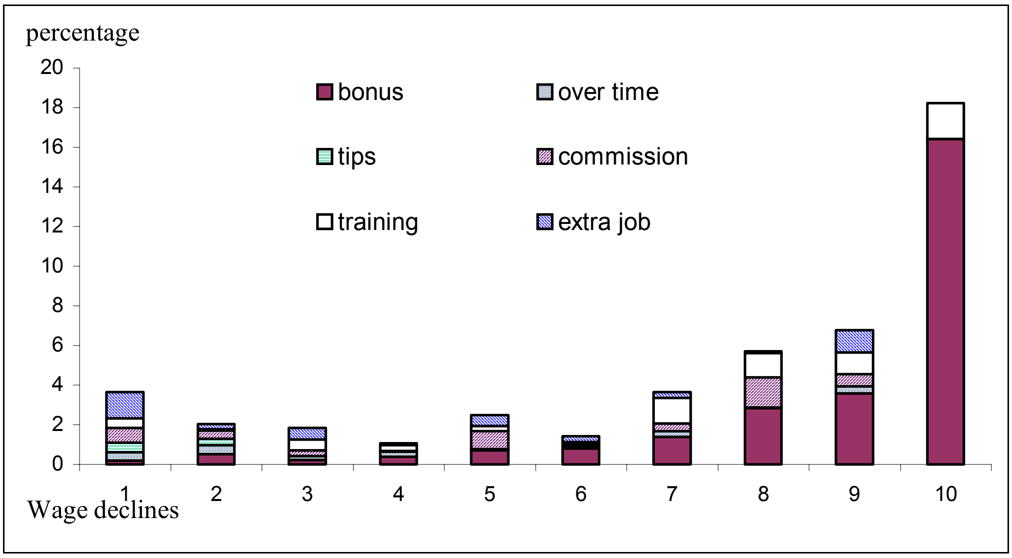
### Figure 2: Proportion of unstable earnings component by income decile* (1970s and 1990s)




* Based on Table 2.

In order to strengthen this result, Figure 3 describes the unstable component of income according to type of earnings, by decile. It is readily seen that the growth of non-fixed components, especially in the top decile, resulted from an increase in bonuses, items directly related to workers' performance and to the firm where they are employed.

**Figure 3: The unstable component of income according to type of earnings (2001)**




Source: PSID. About 700 workers were examined in the 1970s and about 3,000 in the 1990s; all workers were heads of households

To conclude this part, it was found that the two variables examined — employment stability and wage stability — indicate changes in labor market risk levels over the past 30 years. These empirical findings support the conclusions predicted by application_of the theoretical model. In the next part of the paper, we examine whether the workers' individual risk-aversion exerted any effect on their level of adaptability in the context of the changes observed at the close of the twentieth century.

## 4. Worker risk-aversion

Worker risk-aversion was constructed from responses to a questionnaire attached to the core of the 1996 PSID survey, which is repeated annually in the US. The estimates of level of worker risk-aversion used were those published by Barsky et al. (1997). Examination of individual data according to the variable risk-aversion revealed that rising worker risk-aversion is associated with increasing average age, a decreasing proportion of self-employment and an increasing proportion of government employment. Despite these findings, no distinct trend indicating education level or average wage as a function of risk-aversion can be identified for the respective period at this stage.

Job stability, however, was shown to be dependent on the level of risk-aversion. Table 3 shows that during the 1980s to the 1990s, at almost every level of risk-aversion, the average number of times that a worker shifted to another sector rose with every movement toward the risk-taking. To illustrate, risk-averse workers changed sector an average of 1.9 times during the 1980s; risk-taking workers, however, changed sector an average of 2.7 times in the same decade. Also prominent is the considerable increase in the number of times that workers changed jobs between the 1970s and the 1980s. (These results are similar to those reported in Part 2.)

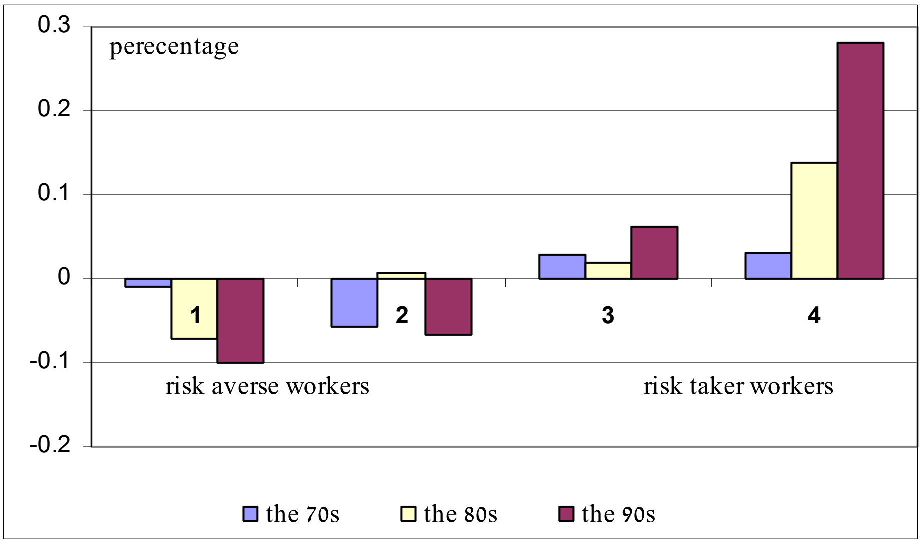
The rate of movement from one sector to another for each risk-averse group in comparison to the average rate of job change in the market is described in Figure 4. Among risk-averse workers (groups 1 and 2), the average rate of movement between sectors is below the average rate of job change in the market; the opposite holds for risk-taking workers (groups 3 and 4). Moreover, given that the rate of movement between sectors in the 1970s was not significantly different between the groups, the differences between the groups accentuated in the 1990s.

**Table 3: Number of Times that Workers Changed Jobs between Sectors Decade and Risk-Aversion Level (1970s, 1980s and 1990s)**

| Risk-Aversion Level | Group 1 (Risk-Aversion) | Group 2 | Group 3 | Group 4 (Risk-Taking) |
|---|---|---|---|---|
| **1970s** | 0.40 | 0.32 | 0.42 | 0.57 |
| **1980s** | 1.90 | 2.17 | 2.34 | 2.67 |
| **1990s** | 1.91 | 1.95 | 2.15 | 2.60 |

Source: PSID. About 400 workers were examined in the 1970s, about 1,000 in the 1980s and about 3,000 in the 1990s; all workers were heads of households. Data is based on heads of households aged 25-65 who consecutively participated in the labor market from the 1970s to the 1990s.

**Figure 4: Rate of Movement between Sectors for Each Risk-Averse Group in Comparison to Average Rate of Job Change in the Market* (1970s, 1980s and 1990s)**




*Based on data from Table 3.

We next examine the influence of worker risk-aversion on wage performance by estimating a series of wage equations. The equations were estimated with data taken from the PSID database for the years 1980-2001. At the first stage of the estimation, several panel equations were estimated for all workers together as well as for groups separately by their level of education. At the second stage, the regression equation was estimated for workers' fixed effect (which was calculated in the first stage of the estimation procedure) using the level of worker risk-aversion as one of the explanatory variables.

**Table 4: Influence of Risk-Aversion on the Wage Fixed Effect***

| | Population Changing Jobs between Decades | | Stable Population | |
|---|---|---|---|---|
| | 1980s | 1990s | 1980s | 1990s |
| All workers | -0.170<br>(0.000) | -0.130<br>(0.000) | -0.227<br>(0.000) | -0.134<br>(0.006) |
| High school dropouts | -0.026<br>(0.850) | -0.318<br>(0.000) | -0.095<br>(0.486) | -0.337<br>(0.073) |
| High school graduates | -0.127<br>(0.000) | -0.114<br>(0.000) | -0.402<br>(0.004) | -0.166<br>(0.007) |
| College graduates | -0.196<br>(0.001) | **0.150**<br>(0.042) | -0.250<br>(0.001) | 0.025<br>(0.743) |

Note: *Level of significance noted in parentheses.

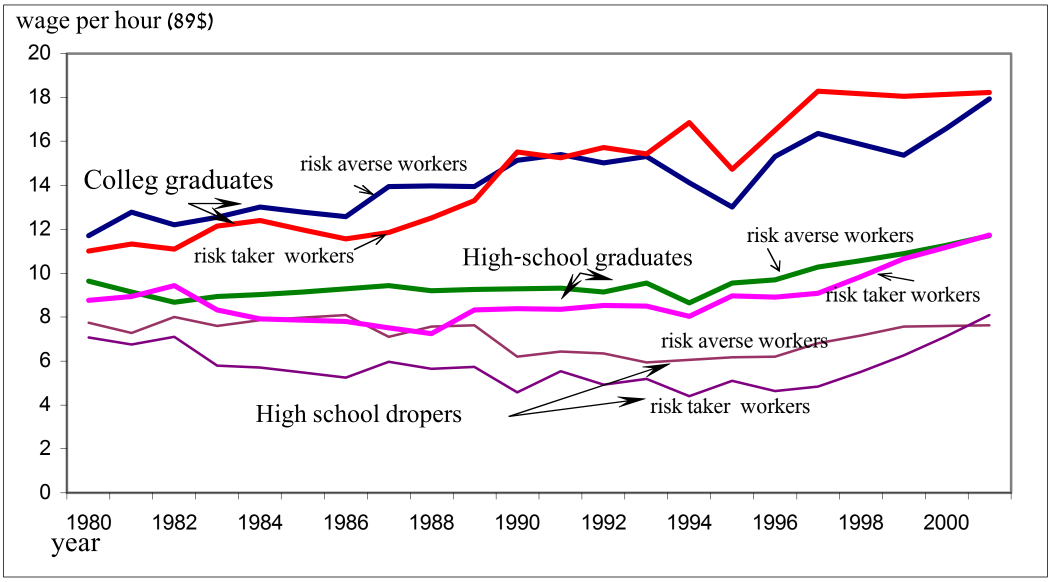
The regression results indicate that during the two decades in question, wages of risk-taking workers were significantly lower than were wages of risk-averse workers (see Table 4). This result is surprising because of the expected relationship between taking steps involving considerable risk and high compensation. Yet, the result can be explained by other factors characteristic of risk-taking workers, especially the relatively high instability characterizing their labor market behavior, a factor that interferes with their ability to benefit from on-the-job training and long-term specialization.[9]

[9] The importance of on-the-job training has been stressed by Becker (1962), Oi (1962), Hashimoto (1981) and Arnott and Stiglitz (1985), among others.

The general picture portrayed by the analysis of the wages earned by risk-taking workers is clarified when we examine the influence of risk-aversion on the wage performance of workers having obtained different levels of education (see Table 4). It was found that (a) the wage gap between risk-averse workers and risk-taking workers declined between the 1980s and the 1990s at almost every level of education (excluding workers who acquired less than a high school education; for these workers, the wage gap remained significant throughout the 1980s); (b) the wage gap between risk-averse and risk-taking workers decreased, in almost all estimations, with each increase in education level; and (c) during the 1990s, risk-taking college graduates earned more than their risk-averse peers.

Moreover, these same trends appeared in the regression estimation, as apparent from Figure 5. This figure describes the wage performance of workers who worked continually throughout the 1980s and 1990s. The picture drawn from the figure makes it quite blatant that during the 1980s and 1990s, a change transpired in the wage gap between risk-averse and risk-taking workers at every level of education: Among college graduates, the gap began to narrow as early as the 1980s; by the 1990s, the wages of risk-taking graduates exceeded those of risk-averse graduates. In contrast, among poorly educated workers, the opposite trend developed over the two decades. Thus, after the wage gap widened between risk-averse and risk-taking workers during the 1980s, this gap then narrowed in the 1990s, until by the end of the decade, the wages of risk-taking workers resembled the wages of risk-averse workers among high school graduates as well as high school dropouts.

**Figure 5: Wage Performance by Education and Risk-Averse Groups\ 1990-2001**




Source: PSID. Based on heads of households who worked continually throughout the 1980s and 1990s.

In order to reinforce the relationship between labor market dynamics, worker wage aversion and wage performance, an additional wage estimation was conducted. In this equation, the explanatory variable *level of worker risk-aversion* was replaced by the change in the number of times that workers changed sectors between the 1980s and the 1990s. As mentioned, this variable was found to be associated with the worker risk-aversion index (all the other variables in the regression remained the same).

The results indicate that during the 1980s, the change in the number of times that a worker moved between sectors affected income through its influence on two factors: employment instability on the one hand, and worker adaptability to labor market transformations on the other (see Table 5). The first factor — employment instability — reduced wages in the short term. However, due to the influence of the second factor — worker adaptability — the negative effect of employment instability declined with each increase in level of education. In contrast, during the 1990s, changes in the rate of job change between the 1970s and the 1980s positively influenced wage performance inasmuch as the short-term negative effect of employment instability during the 1980s evaporated, leaving worker adaptability — which rose with increasing level of education — to exert a positive effect on wage performance.

**Table 5: Influence of Changes in Number of Sector Changes between Decades on Worker Fixed Effect**

| | **1980s** | **1990s** | |
|---|---|---|---|
| Explanatory variable: change in number of times that workers changed jobs between sectors | From the 1970s to the 1980s | From the 1970s to the 1980s | From the 1980s to the 1990s |
| All workers | -0.053 (0.000) | 0.028 (0.025) | -0.025 (0.225) |
| High school dropouts | -0.083 (0.008) | 0.031 (0.401) | 0.039 (0.522) |
| High school graduates | -0.053 (0.003) | 0.012 (0.041) | -0.067 (0.075) |
| College graduates | -0.031 (0.000) | 0.084 (0.002) | 0.050 (0.059) |

Note: *Level of significance noted in parentheses.

Results of the regression support the model's conclusions as described herein regarding the strengthening relationship between wages and worker attitudes toward risk. The results indicate relative improvement in the wages of risk-taking workers during the last two decades. Thus, the results enable us to form a clear picture of the transformations experienced by the economic environment and their influence on wages. The majority of changes in this environment, which evolved in 1980s, required adaptation by the entire work force even though their effect on wage performance was significant only for educated workers (college graduates), especially for the risk-takers among them. The increase in the relative wages of educated risk-taking workers was found to be among the factors expanding the wage gap **between** educated and non-educated workers during the 1980s, and **within** the group of college-educated workers due to the salience of worker adaptability. At the same time, the wage gap also narrowed between risk-taking and risk-averse workers among educated workers when controlling for adaptability.

During the 1990s, the influence of hi-tech industries strengthened and spread;[10] among college graduates, the wages of risk-taking workers exceeded those of risk-averse workers during the same period. At the same time, high school graduates began to enjoy the fruit of these technological changes, followed in the 1990s by a process similar to that experienced by college graduates during the 1980s: this group's ability to adapt became more important, and the wage gap between risk-taking and risk-averse high school graduates narrowed. And, despite the fact that it is still impossible to estimate the significance of the level of risk-aversion for wage performance among workers having less than 12 years of education, in light of the trends characterizing their wages (as seen in Figure 5), it appears that the process experienced by this group of workers in the 1990s, but especially during the second half of the decade, resembled the trend observed among more educated workers.

## 5. Conclusion

The relationship between technological change, worker risk-aversion and wage performance has been studied to date primarily from only one perspective, that of how technology influences worker wages and how wage changes affect worker risk-aversion. In the research reported here, the same problem was investigated from the opposite perspective by asking: How does worker risk-aversion affect wage performance during a period of technological change?

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[10] Some argue that the "real" technological revolution observed at the close of the twentieth century had occurred only in the 1990s, with expansion of computer use, the Internet, and their application to the entire population in every area of daily life; see Bresnahan, 1999; Breshnaham, Brynjolfsson and Hitt, 2002.

It was found that the relationship between the two variables is two-dimensional: on the one hand, technological change drives up the level of economic risk-aversion; on the other hand, these same advances reinforce the relative advantage of risk-taking workers, who more easily adapt to the new environment and enjoy rising relative wages.

The research showed that the US labor market has been characterized in the last two decades by a growing rate of job and sector change, a trend particularly prominent during the transition from the 1970s to the 1980s. It was also found that during the last 20 years, exposure to wage shocks has increased. Analysis of worker responses to these trends indicates that risk-taking workers adapted themselves to labor market transformations more readily than did risk-averse workers.

It was also found that the behavior of risk-takers, especially their relative employment instability, interfered with their earnings path; they therefore they earned less, on average, than did their peers. However, the wage gap between risk-averse and risk-taking workers gradually narrowed in the last two decades: for college graduates the process started in the 1980s; for less-educated workers it started in the 1990s.

Taken together, these results indicate an alternative perspective on the relationships holding between technological change, adaptability, risk-aversion and wages. Nevertheless, the strong relationship found between these variables was affected by the unique dynamics characterizing the economic environment at the close of the twentieth century. Collapse of the dreams held by many at the dawn of the twenty-first century, especially in the hi-tech industries, indicates that in these markets, the boundary between dramatic achievement and glaring failure is especially thin, and that the windows of opportunity opened to risk takers at the end of the twentieth century apparently did not remain so for long.

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## Appendix 1: Proof of Proposition I

The utility function is (all signs as define in the paper):

1. $U(W)=\frac{1}{1-\varphi}\cdot W^{1-\varphi}, \qquad U'(W)=W^{-\varphi}, \quad U''(W)=-\varphi\cdot W^{-(\varphi+1)}$

2. $W=\beta\cdot\mu\cdot g-m$.

For $\theta<0$ the utility function is concave. Workers will prefer to work in the risky sector and the gap between the wage in the secure sector to the risky one will be negative. This case is inconsistent with the model's assumptions and therefore irrelevant..

For $\theta\neq 1,\ \theta>0$ the utility function is convex. (For $\theta=1$ the function is not defined).

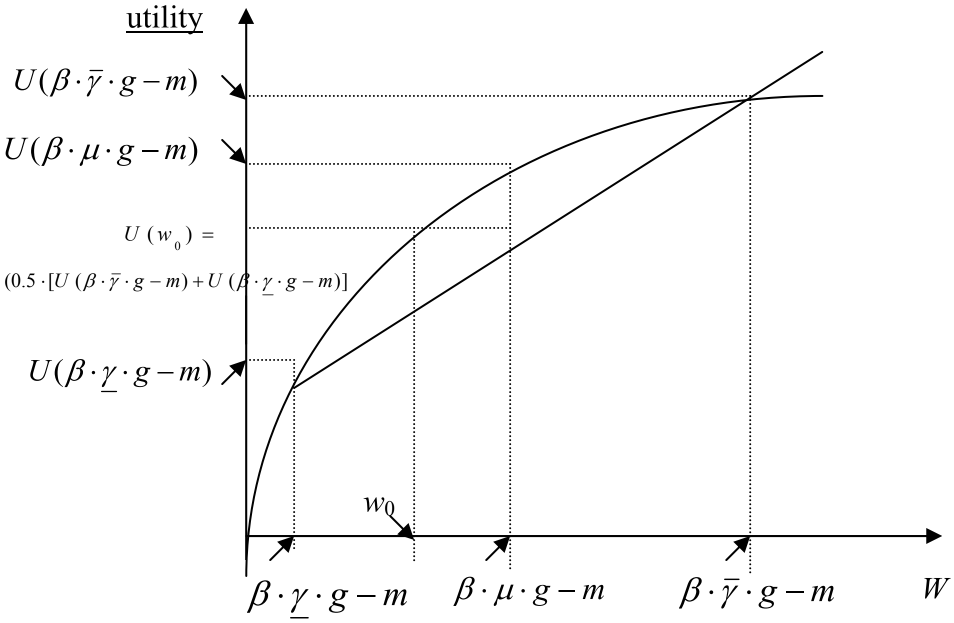


**Figure 1a: The utility function**

As a result of the convex assumption we can write:

3. $U(\beta\cdot\mu\cdot g-m)-(0.5\cdot[U(\beta\cdot\bar{\gamma}\cdot g-m)+U(\beta\cdot\underline{\gamma}\cdot g-m)]>0,$

and as a result of the continuity assumption we can write:

4. $U(\beta\cdot\underline{\gamma}\cdot g-m)-(0.5\cdot[U(\beta\cdot\bar{\gamma}\cdot g-m)+U(\beta\cdot\underline{\gamma}\cdot g-m)]<0.$

Therefore, there is a $w_0$ in the range $[(\beta\cdot\mu\cdot g-m),\ (\beta\cdot\underline{\gamma}\cdot g-m)]$ that fulfill:

5. $U(w_0)-(0.5\cdot[U(\beta\cdot\bar{\gamma}\cdot g-m)+U(\beta\cdot\underline{\gamma}\cdot g-m)]=0,$

When:

6. $(\beta\cdot\underline{\gamma}\cdot g-m)<w_0<(\beta\cdot\mu\cdot g-m)$.

Define:

7. $w_0 \equiv (\beta \cdot \mu \cdot g - k - m)$

and:

8. $c \equiv k/(\mu \cdot g)$,

Then we get that for every set of $g, m, s$ and $\mu$ there is a positive $c$ that fulfills:

9. $U((\beta - c) \cdot \mu \cdot g - m) = 0.5 \cdot [U(\beta \cdot \bar{\gamma} \cdot g - m) + U(\beta \cdot \underline{\gamma} \cdot g - m)]$,

in other words:

10. $\Delta U = 0$.

**Appendix 2:**

Proposition: There is a positive relationship between the level workers' risk-aversion and the wage gap between the risky and secure sectors when $\Delta U = 0$.

Proof:

The equality from equation 8 in the paper can be written as (for simplicity we assume m=0):

1. $(x_1)^\alpha = 0.5 \cdot ((x_2)^\alpha + (x_3)^\alpha)$,

when:

2. $x_1 = (\beta - c) \cdot g \cdot \mu, \quad x_2 = \beta \cdot g \cdot \underline{\gamma}, \quad x_3 = \beta \cdot g \cdot \bar{\gamma}, \quad \alpha = 1 - \theta$.

Algebraically we get:

3. $x_1 = x_2 \cdot (\frac{1 + u^\alpha}{2})^{1/\alpha}, \quad u \equiv x_3 / x_2 > 1$.

Define:

4. $z \equiv \alpha \cdot \ln(u), \quad k \equiv \ln(u), \quad u > 1 \quad \Rightarrow \quad z,\ k > 0$,

then we can write equation 3, above, as:

5. $x_1 = x_2 [(\frac{1 + e^z}{2})^{1/z}]^k$

Because $x_2 > 0$ and $k > 0$, it is sufficient to confirm the relationships between:

6. $x_1 = (\frac{1 + e^z}{2})^{1/z}$.

Or:

7. $\ln(x_1) = (1/z) \cdot \ln(\frac{1 + e^z}{2})$,

If we derivate the two sides of the equation we get:

8. $\frac{x_1'}{x_1} = -\frac{1}{z^2} \cdot \ln(\frac{1 + e^z}{2}) + \frac{1}{z} \cdot \frac{e^z}{1 + e^z}$,

Define:

9. $\rho = \dfrac{1}{1+e^{z}} \;\Rightarrow\; 0 < \rho < 0.5$

So, equation 8, above, can be written as:

10. $x_1' = \dfrac{x_1}{z^2} \cdot [\ln(2) + \ln \rho + \ln \dfrac{(1-\rho)}{\rho} \cdot (1-\rho)].$

Or as:

11. $x_1' = \dfrac{x_1}{z^2} \cdot [\ln(2) + \rho \cdot \ln\rho + (1-\rho) \cdot \ln(1-\rho)] \;\equiv\; \dfrac{x_1}{z^2} \cdot h(\rho),$

By definition $0 < \rho < 0.5$; therefore:

12. $h'(g) = \ln(\dfrac{\rho}{1\text{-}\rho}) < 0$ , $\quad h''(g) = \dfrac{1}{\rho} + \dfrac{1}{1-\rho} > 0.$

And because $h(\rho)$ is positive in the relevant range (when $\rho$=0.5 defines the minimum point), we got a positive relationship between $x_1$ and $z$ and, therefore, a positive relation between $\theta$ and $c$.

## Appendix 3: Proof of Proposition II

**For $\theta$=1 the solution is:**

1. $\Delta U = \ln((\beta - c) \cdot \mu \cdot g - m) - \dfrac{1}{2} \cdot [\ln(\beta \cdot \overline{\theta} \cdot g - m) + \ln(\beta \cdot \underline{\theta} \cdot g - m)] < 0,$

2. $\ln \dfrac{((\beta - c) \cdot \mu \cdot g - m)}{[(\beta \cdot \overline{\theta} \cdot a - m)(\beta \cdot \underline{\theta} \cdot a - m)]^{1/2}} < 0$ .

3. $\dfrac{((\beta - c) \cdot \mu \cdot g - m)}{[(\beta \cdot \overline{\theta} \cdot g - m)(\beta \cdot \underline{\theta} \cdot gm)]^{1/2}} < 1,$

4. $((\beta - c) \cdot \mu \cdot g - m))^2 < (\beta \cdot \overline{\theta} \cdot g - m) \cdot (\beta \cdot \underline{\theta} \cdot g - m),$

5. $\dfrac{g}{m} > \dfrac{\beta \cdot (\overline{\theta} + \underline{\theta}) - 2 \cdot (\beta - c) \cdot \mu}{\beta^2 \cdot \mu^2 + \beta^2 \cdot \overline{\theta} \cdot \underline{\theta} + c \cdot (2 \cdot \beta - c) \cdot \mu^2}.$

Since $(\overline{\theta} + \underline{\theta}) = 2 \cdot \mu$ and $\sigma^2 = (\mu^2 - \overline{\theta} \cdot \underline{\theta})$:

6. $\dfrac{g}{m} > \dfrac{2 \cdot c \cdot \mu}{c \cdot (2 \cdot \beta - c) \cdot \mu^2 - \beta^2 \cdot \sigma^2}.$

**For $\theta$= 2 the solution is:**

7. $$\Delta U = ((\beta - c)\cdot \mu \cdot g - m)^{-1} - \frac{1}{2}\cdot [\ (\beta \cdot \overline{\gamma} \cdot g - m)^{-1} + \ (\beta \cdot \underline{\gamma} \cdot g - m)^{-1}]$$

.8. $$\frac{g}{m} > \frac{\beta \cdot (\overline{\theta} + \underline{\theta}) + 2 \cdot c \cdot \mu - 2 \cdot \beta \cdot \mu}{\beta^2 \cdot (2 \cdot \mu^2 - 2 \cdot \overline{\theta} \cdot \underline{\theta}) - 2 \cdot \beta \cdot c \cdot \mu^2}) = \frac{\mu \cdot c}{\beta \cdot (c \cdot \mu^2 - \beta \cdot \sigma^2)}$$