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ABSTRACT

Iceland's Natural Experiment in Supply-Side Economics*

The move to a pay-as-you-earn income tax system in Iceland in 1987–8 made income earned in 1987 tax-free. Using a sample of 9,274 individuals for the years 1986, 1987 and 1988, we calculate the labour-supply response of this change and find that total labour supply rose by 6.7% in 1987 over the average of 1986 and 1988 when we correct for entry in 1988. This consists of an 8.6% increase in weeks supplied by those already in the labour market in 1986 and a 1.9% decline due to entry/exit. The elasticity of weeks worked to the rise in after-tax wages was 0.41 for men and 0.11 for women. While the participation rate of women increased somewhat in our sample, participation by men fell.

JEL Classification: E65, J22
Keywords: supply-side economics, labour supply

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NON-TECHNICAL SUMMARY

A natural experiment in supply-side economics took place in Iceland in 1987. In 1987–8, Iceland moved from a system under which taxes were paid on previous year's income to a pay-as-you-earn system. The transition to the new system created a gap in the tax base and a tax-free year emerged. Once the new system was in place in 1988, the tax base had also shifted over to that year but the tax base in 1987 was income earned in 1986: income earned in 1987 was never taxed.

This experiment creates a unique opportunity to study the labour supply response of individuals who were temporarily faced with a zero marginal and average income tax rate. Moreover, the income effect was reduced because workers were still paying taxes, although not of income earned in 1987. For this reason, we are able to find an upper limit on the effect of tax cuts on labour supply. The *employment rate* defined as the ratio of the total number of weeks worked in a given year, on the one hand, and the potential supply by all working-age individuals, on the other hand, jumped by around 3% from 1986 to 1987 and then dropped from 1987 to 1988 down to its earlier level. The response by women was slightly larger; an increase of 4.16% while that for men rose by 2.36%. There were also significant output effects. The rise in labour supply coincided with an 8.5% increase in real GDP in 1987. When compared to the average of 1986 and 1988, real GDP was 4.16% higher. We note that the rise in GDP can also be traced to a favourable terms-of-trade development and an increase in domestic demand.

We study a cross-section of individuals in the period surrounding the tax reforms to learn about the responsiveness of labour supply to the tax cuts. This enables us to determine the effect on labour-force participation, the effect on the number of weeks supplied by each worker, the distribution of labour supply across our sample, the income distribution and an assessment of the determinants of the labour-supply response: in particular, we can estimate how the change in the supply of labour depends on observable characteristics such as age, gender, previous income and the number of children. By looking at the response of labour supply during the tax-free year in Iceland in 1987, using a sample of 9,274 workers out of a total of 180,577 in that year, we come to the following conclusions:

- There is a large variation across individuals in their labour-supply response. Some workers (2,455) decided to work less in 1987 while others (3,860) decided to work more.

- When averaging across the whole sample, the elasticities of labour supply fall close to those reported by Killingsworth (1983) for American workers.

The elasticity of weeks worked to the rise in after-tax wages was 0.26 for all workers, 0.41 for men, and 0.11 for women when looking at all workers: both those who were employed in 1986 and those who decided to join in 1987. The elasticity of earnings was 0.61 for men and 0.72 for women with an average of 0.67. The higher elasticity using earnings is partly explained by an increase in real wages.

- Looking only at workers who were employed in 1986, men responded more than women. Men who received some income from self-employment in 1986 had a considerably higher elasticity of labour and increased their labour supply by 24.1%, compared to the 14.3% increase by all men. Single men also had a slightly higher elasticity. Similarly, single women were the group of women that showed the largest positive supply response.

- The increase in labour supply during the tax-free year - measured either by the number of weeks worked or earnings - is a positive function of the tax rate in previous year for tax rates between 20% and 40% but independent of the tax rate outside of this range.

- The participation rate for men in our sample fell in all cases while that for women tended to increase. The increase was most significant for young workers and married women.

- The density of (gross) earnings has one mode (if we omit workers not in employment) while the density of weeks worked has two: corresponding to part-time and full-time work. In 1987, the frequency of higher earnings and weeks worked increased significantly and, most importantly, the variance of the earnings distribution increased significantly.

Iceland's Natural Experiment in Supply-side Economics

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The move to a pay-as-you-earn income tax system in Iceland in 1987-1988 made income earned in 1987 tax free. Using a sample of 9,274 individuals for the years 1986, 1987 and 1988, we calculate the labour-supply response of this change and find that total labour supply rose by 6.7% in 1987 over the average of 1986 and 1988 when we correct for entry in 1988. This consists of an 8.6% increase in weeks supplied by those already in the market in 1986 and a 1.9% decline due to entry/exit. The elasticity of weeks worked to the rise in after-tax wages was 0.41 for men and 0.11 for women. The elasticity of earnings was 0.61 for men and 0.72 for women. While the participation rate of women increased somewhat in our sample, participation for men fell.

Keywords: Supply-side economics, labour supply.
JEL Classification: E65, J22.

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The supply-side experiment in the United States under President Reagan received world-wide attention. The massive tax cuts agreed in 1981, and implemented in 1982, preceded a period of spectacular growth starting in the fall of 1983 and lasting until

the beginning of the 1990s. While the proponents of supply-side economics have taken this epoch as a proof of the soundness of their policy recommendations, the verdict among academic economists is more mixed. While a majority appears to accept significant effects of taxes on incentives—to work, save and invest—they do not think that these effects are empirically very strong (see e.g. Feldstein, 1986). The emerging consensus has been supported by a vast literature on the microeconomic evidence for the effect of tax cuts on labour supply.[1]

A much less noticed experiment took place in Iceland, a country with a population of only 1/1000 that of the US. This experiment is in many ways better suited to judge the empirical significance of the supply-side effects of income tax cuts. In 1987-1988, Iceland moved from a system under which taxes were paid on previous year's income to a pay-as-you-earn system. The transition to the new system created a gap in the tax base and a tax-free year emerged. Once the new system was in place in 1988, the tax base had also shifted over to that year but the tax base in 1987 was income earned in 1986: income earned in 1987 was never taxed.[2]

This experiment creates a unique opportunity to study the labour supply response of individuals who were temporarily faced with a zero marginal—and average—income tax rate. Moreover, the income effect was reduced because workers were still paying taxes, although not of income earned in 1987. For this reason, we are able to find an upper limit on the effect of tax cuts on labour supply. The notable effect on labour supply can be seen in the figure below which has the *employment rate* defined as the ratio of the total number of weeks worked in a given year, on the one hand, and the potential supply by all working-age individuals, [3] on the other hand, for the period 1960-1996. The rate jumps by around 3% from 1986 to 1987 and then

[1] The positive response of labour supply to a cut in income taxes has been documented in a number of studies (see e.g. Hausman, 1981a, 1981b; Fullerton, 1982). Hausman finds that replacing the progressive system of income taxation with a linear income tax would raise hours of work. However, cutting taxes does not lead to a sufficient rise in labour supply to increase tax revenue. Fullerton also finds the U.S. to the left of the peak of its Laffer curve.

[2] The collection of income tax in the former system involved two steps. In the first half of the year, each individual's tax payment was based on his previous year's taxable income—which was earned two years before. In the second half of the year, when taxable income—earned in the previous year—became known, he paid the difference between this forward payment and the actual amount due in income tax.

[3] The employment rate is calculated from individual registration in a database for entitlements related to work accidents. The database has the number of working weeks of all Icelandic workers.

drops from 1987 to 1988 down to its earlier level.[4] The response by women was slightly larger; an increase of 4.16% while that for men rose by 2.36%. There were also significant output effects. The rise in labour supply coincided with a 8.5% increase in real GDP in 1987. When compared to the average of 1986 and 1988, real GDP was 4.16% higher. We should note that the rise in GDP can also be traced to a favourable terms-of-trade development and an increase in domestic demand.

Figure 1
The employment rate in Iceland, 1960-1996.

Figure 2 Rate of Growth of Real Output

In this paper we study a cross-section of individuals in the period surrounding the tax reforms to learn about the responsiveness of labour supply to the tax cuts. This enables us to determine the effect on labour-force participation, the effect on the number of weeks supplied by each worker, the distribution of labour supply across our sample, the income distribution, and an assessment of the determinants of the labour-supply response: in particular, we can estimate how the change in the supply of labour depends on observable characteristics such as age, gender, previous income and the number of children. Our analysis is a statistical description of the data rather than an estimation of any particular model of labour supply. We relegate a formal intertemporal model of labour supply to an appendix.

[4] The fall in the employment rate after 1988 was to some extent caused by a rise in unemployment. Unemployment averaged 0.7% in 1980-1986 and 3.0% in 1988-1996. The annual unemployment rates were as follows:

	%		%		%		%		%
1984	1.3	1987	0.5	1990	1.8	1993	4.4	1996	4.3
1985	0.9	1988	0.6	1991	1.5	1994	4.8	1997	3.9
1986	0.7	1989	1.7	1992	3.0	1995	5.0	1998	3.0

I. A Note on the Theory of Labour Supply

While our emphasis will be on describing the data without resorting to any formal modelling, we would like to start out by stating, for the record, some economic intuition.

Assume that utility depends positively on consumption C and negatively on labour supply L: $u(C, L)$, $u_C > 0$, $u_{CC} < 0$, $u_L < 0$, $u_{LL} < 0$. A (continuous-time) model of consumption- and leisure choice (see appendix) gives the following first-order condition for a representative individual where w denotes wages and τ is a (proportional) tax on wage income.[5]

$$u_L = -u_C w(1-\tau) \tag{1}$$

The left-hand side has the marginal cost of increasing labour supply while the right-hand side has the marginal benefit. The marginal cost is the disutility of increased work while the marginal benefit is the utility of the increased consumption thus made possible: by working more we gain $w(1-\tau)$ which gives consumption valued at u_C.

A temporary (marginal) tax cut—that leaves the tax burden unaffected as it is replaced by an identical lump-sum tax (based on past income)—affects τ in the equation and only consumption and u_C as a result of an induced labour-supply response: the substitution effect dominates the income effect. Because of the fall in τ labour supply rises instantly, raising the marginal disutility of labour. However, labour supply will have fallen below its initial level when taxes are eventually raised again because wealth accumulates during the period of higher-than-normal labour supply which reduces the marginal utility of consumption and hence also the marginal benefit of working. This is an income effect. Following the tax-free period we then have high, but falling, consumption and low, but rising, labour supply as we gradually converge back to the original steady state.

It should be clear from this discussion that the labour-supply response may differ across individuals since the elasticity of intertemporal substitution depends on the form of the utility function. Thus, to name one example, workers with dependent children who cannot easily lengthen their working hours due to domestic responsibilities may have a low elasticity of substitution.

[5] The equation is derived from two first-order conditions describing optimal consumption and labour supply (see appendix).

II. A Chronicle of Events

A. *The tax reforms*

The Icelandic government decided in the fall of 1986 to simplify the personal income tax system. There appears to have been a broad consensus that such reforms were justified although previous attempts at introducing a pay-as-you-earn system in 1977 and 1981 had been unsuccessful. Following a request from labour unions and industry, which formed a part of a wage settlement in December 1986, tax reforms were put on a fast track with the introduction of a pay-as-you-earn income tax to be effective at the beginning of 1988. At the same time there was political willingness to increase the redistribution of income through the personal-income-tax system.

In spite of a low average tax-burden of the personal-income tax in comparison with the other Nordic countries (14.5% of average blue collar income in 1985,[6] relative to an average of 32% in the other Nordic countries), the marginal rate could go as high as 56.3%. So in order to shift the tax burden from the lowest income earners, and at the same time reduce the marginal rates at the high end of the income distribution, the following changes were made.

- Four distinct tax brackets were consolidated—both state and local—into a single bracket of 35.2%.
- A single personal tax-allowance was introduced to replace various deductions dependent on family status and income.
- A special scheme for interest deductions and tax credits for owner-occupied houses was introduced.
- Benefits (such as child-benefits) were to be paid out directly instead of being part of the tax system.

The table below summarises some of the key changes in the tax system in 1987.

[6] This applied to a single individual, married people enjoyed lower rates.

Table 1 Average- and marginal tax rates (single individuals)
(in thousands of Icelandic kronas)

	1986	1988	Change
Threshold of taxable income, (current prices)	197	530	170%
Lowest marginal rate (%)	28.3	35.2	6.9
Highest marginal rate (%)	56.3	35.2	-21.1
Average wages, thousand IKr (current prices)	390	686	76%
Threshold of taxable income as per cent of average wages (%)	50.5	77.3	26.8
Average tax (%)	14.5[7]	8.0[8]	-6.5

Source: Ministry of Finance (1997).

The announcement about the impending change in the tax system was made only a couple of months before the legislative procedure was finalised. As a result, households and the corporate sector did not have much room to respond to the news prior to the changes becoming effective. Because the announcement was made in late 1986, we can eliminate the possibility that changes in labour supply occurring in 1986 had anything to do with the tax free year.[9]

B. *Economic conditions around the time of the tax reforms*

Being prone to fluctuations arising from the importance of natural resources (fishing and fish processing), the Icelandic economy was in a strong upswing at the time of the tax reforms. Prior to the announcement, employment had been rising and the labour-force participation rate was at an all time high at 80% in 1986. With unemployment at only 0.7%, and the labour market in a state of excess demand, inflation was running at 20-30 % annually.

[7] Figure taken from OECD (1998) and applies to 1985.
[8] Calculated from lines 1-5 in table.
[9] However, it is possible—and in fact quite likely—that self-employed workers moved some income from 1986 to 1987. Thus income earned in 1986 may have been reported in 1987 to avoid taxation.

On the external side, the current account moved temporarily into a surplus in 1986 following continuous deficits since the late 1970s. This favourable outcome in 1986 was mostly due to a positive terms-of-trade shock. In 1986 and 1987 real GDP rose by 6% and 81/2% respectively. Initially driven by increased exports and an improved terms of trade, the upswing turned from an export-led to a domestic-demand led boom in mid- to late 1987. This followed a 3.3% growth rate in 1985. A collective wage agreement in late 1986 resulted in a 20% increase in nominal wages. However, as it turned out, wages rose by a staggering 40%, and per-capita real disposable income rose by 25%.

It can be argued that the tax reform came at precisely the right time to offset some of the labour market pressures which had build up during 1986 and 1987. In the absence of this "extra" labour supply, the inflation outcome might have been much worse. Price inflation—measured by the GDP price deflator—was 17.8% in 1987, lower than in both 1986 (22.7%) and 1988 (20.6%).

Obviously, the economic situation in 1986-87 was unsustainable with a widening current-account deficit and mounting inflationary pressures. As a result, the government tried to stabilise the economy by tightening fiscal policy, and devaluing the domestic currency. In 1988 and in the following years, the economy cooled down as GDP was stagnant well into the mid 1990s.

III. The Data at First Glance

We now turn to the analysis of the labour supply response of the individuals in our sample. The data set is drawn from two databases. One is individual tax returns (*SOURCE1*), and the other has the number of working weeks for each individual taken from a database compiled by the authorities (in connection with a special employers' insurance charge based on the number of weeks worked) (*SOURCE2*). By merging these two it is possible to establish a one-to-one relationship between individual income and the number of weeks worked.[10] Both have the same system of identification numbers, allowing us to link the number of weeks worked for a given individual from *SOURCE2* to his income and other attributes taken from *SOURCE1*.

[10]Both files are kept at the National Economic Institute, which ensures anonymity of personal information. A major drawback of the data set on working weeks is that each individual can as a maximum work 52 weeks for the same employer. So, someone previously working 52 weeks, but increasing his overtime the following year, is still only counted as working 52 weeks. Only if he takes a second job with another employer will the increase be counted.

We use a random sample of 9,274 individuals, who filed income tax returns in 1986, 1987 and 1988.[11] This gives a total of 27,822 observations, three for each of the 9,274 individuals in our sample. These individuals are randomly chosen and include both workers who are employed, unemployed and out of the labour force. We have data on total direct tax payments, wages earned from salaried employment, wages earned through self-employment, age, gender, marital status, and the number of children.[12]

The sample has 4,668 men and 4,606 women. This includes 2,782 couples. There are 1,236 individuals who have at least some income from self-employment, the rest being employees only. Figure 3 shows average labour supplied in 1986 and 1988, and the supply of labour in 1987 for all 9,274 workers in the sample. We use the average of 1986 and 1988 as a baseline to account for any linear trend in labour supply, earnings or wage rates. Note that the number of weeks worked can exceed 52 when individuals hold more than one job at a time. There is a large variation in the change in labour supply between the two years. Thus some workers (2,762) decided to work less in 1987 while others (4,171) decided to work more. This leaves a large number (2,341) with an unchanged labour supply. The figure shows that workers who raised their labour supply in 1987 did so on average by more than those who reduced it.

Figure 3
Average labour supply in 1986 and 1988 and the supply of labour in 1987

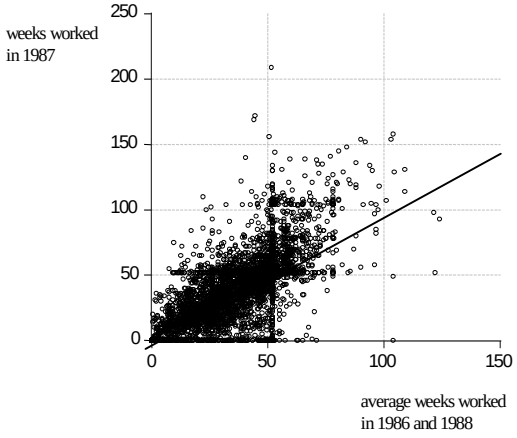
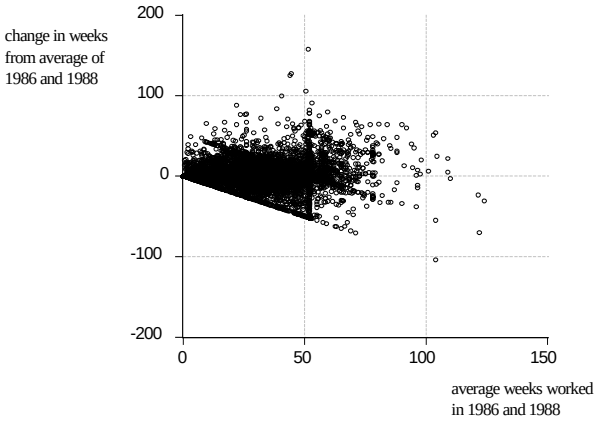


Figure 4
Average labour supply in 1986 and 1988 and the supply response in 1987



[11]It should be noted here that although 1987 was a tax-free year with respect to personal income taxed, individuals had to file a normal tax return. Since all working-age individuals had to file a tax return, no sample-selection bias is created by only sampling among those who filed a tax return in all three years.
[12] All variables are taken from *SOURCE1* apart from the number of weeks worked which is taken from *SOURCE2*.

The 9,274 individuals supplied on average 308,913 weeks of labour in 1986 and 1988, of which the 4,606 women accounted for 122,435 weeks. In 1987, the 9,274 workers in the sample increased their supply of labour from 308,913 to 326,554 weeks, that is by 5.7%. When we correct for entry in 1988—which reduces the measured supply response in 1987—we get a 6.7% rise in weeks supplied. The increase in labour supply by men was slightly higher than the average: they worked 202,252 weeks in 1987 instead of an average of 186,477 weeks for 1986 and 1988, which is an 8.46% increase over 1986—8.8% when we have corrected for entry in 1988. Women in the sample worked 124,302 weeks, an increase of only 1.5%—3.5% when we have corrected for entry in 1988.

Before proceeding any further, it is interesting to look at the relationship between the change in labour supply in 1987 from the average level for 1986 and 1988, on the one hand, and the average level of labour supply in 1986 and 1988, on the other hand, to see if workers who increased their supply of labour worked part-time, full-time, or not at all in 1987. This is Figure 4. We notice clusters at full employment in that year. Besides this, no relationship is apparent. Thus part-time workers do not seem to respond more than others to the tax change. Note that the straight line arises because the number of weeks worked is bounded from below by the zero-weeks constraint.

The problem with the number of weeks worked as a measure of labour supply is that it does not capture changes in hours per week. With a constant hourly wage, changes in earnings measure both changes in the number of weeks and in hours per week. For this reason we do the same calculations using the change in earning as a measure of the labour-supply response. Earnings are measured as the sum of wage income and income from self-employment, both measured in real terms (1986 kronur). However, this may overestimate the labour-supply response because real wages did increase from 1986 to 1987 as shown in Table 2.

Table 2 Growth of hourly (real) wages for blue-collar workers (including overtime)

	%		%		%
1984	-1.3	1986	5.3	1988	3.4

1985	3.7	1987	18.2	1989	-5.5

Figures 5 and 6 correspond to Figures 3 and 4 but use earnings instead of weeks worked. The pattern of observations is similar although the supply response may be easier to detect in Figure 5 than in Figure 3.

Figure 5
Average earnings in 1986 and 1988 and earnings in 1987.

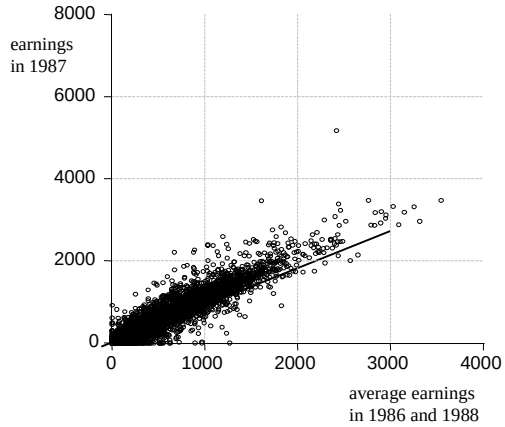
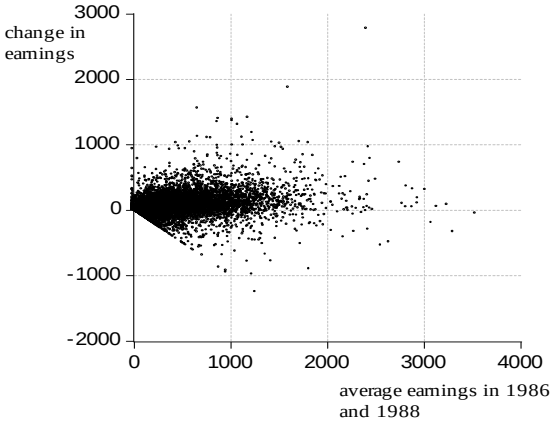


Figure 6
Average earnings in 1986 and 1988 and the supply response in 1987



The question arises whether the changes in labour supply are primarily caused by entry into the labour force or by employed workers changing their supply of weeks. Given the very low unemployment rate in 1986 (0.7%), we define anyone who works at least one week as part of the labour force and those who supply zero weeks as out of the labour force. The following table has the change in the (total) number of weeks and earnings due to entry and exit from employment in 1987, on the one hand, and due to existing workers changing their supply of weeks in 1987, on the other hand. The baseline is the average of weeks supplied in 1986 and 1988. For this reason we add a third line which has the change in this difference due to entry in 1988.

Table 3 Changes in labour supply relative to the average of 1986 and 1988

	weeks				earnings			
	men		women		men		women	
	%		%		%		%	
entry and exit 1987	-1.4		-0.6		-0.0		0.2	
Δweeks/Δearnings	6.6		2.0		8.9		2.9	
entry in 1988	-0.2		-0.8		-0.0		0.0	
sum	5.0	+	0.6	= **5.7**	8.9	+	3.1	= **12.0**

We see that both men and women reduced their supply of weeks due to exit/entry in 1987 while employed men increased their supply significantly. Despite the fact that more women are employed in 1987 than in 1986 (more on this later), their supply of weeks falls from the benchmark case due to entry and exit: the once who quit employment worked more on average than those who joined. When we look at earnings—the sum of wage income and income from self-employment in current prices—a similar pattern is revealed. The key difference lies in the increase in earnings for women due to entry and exit.

Table 4 reports elasticities of supply—for both those workers already in the labour market in 1986 and those who decided to join in 1987—where the elasticities are calculated as:

$$\eta^L = \frac{\sum (L_{87} - L_A)/L_A}{\sum_i T_{86}/E_{86}} \qquad \eta^E = \frac{\sum (E_{87} - E_A)/E_A}{\sum_i T_{86}/E_{86}}$$

L is the number of weeks supplied in a given year, E is earnings (the sum of wage income W and income from self-employment P), and T is the level of income taxes. E_A (L_A) denotes average earnings (weeks) in 1986 and 1988. As before, we use this average to account for any linear trend in labour supply, earnings or wage rates. We note that we use an average tax rate while the marginal one would be preferred. The difference between the two was pointed out in Table 1 above.

Table 4

Elasticity of labour supply — calculated from sample averages

	#obs.	ΔL	L_A	T	E	η^L
men	4,668	3.379 (0.27)	39.948 (0.285)	123,377.0 (2,397.2)	592,001.0 (6,513.36)	0.41
women	4,606	0.405 (0.213)	26.582 (0.285)	36,586.68 (819.974)	260,959.7 (3,265.504)	0.11

	#obs.	ΔE	E_A	η^E
men	4,668	83,936.76 (3,015.61)	654,046.10 (6,761.41)	0.61
women	4,606	29,099.17 (1,492.90)	289,930.70 (3,443.19)	0.72

Standard errors in parentheses.

The average elasticity for both sexes combined is 0.26 when weeks worked are used and 0.67 when earnings are used. The elasticities fall close to those reported by Killingsworth (1983) for American workers. Looking only at the substitution effect—which makes the estimates most comparable with our experiment—the Killingsworth estimates range from –0.05 to 0.50 for men and from 0.50 to 1.65 for women. While our estimate for men falls within this range, this is not so for women when weeks-worked are used. However, when using the earnings measure, the elasticity for women does fall within the range.

We will now look separately at the response by those workers supplying at least one week of labour in 1986 and those who did not work at all in that year. Given the low rate of unemployment in 1986 (0.7%) we can look at the latter as a labour-force participation decision. In this section we will first describe the data informally along these lines while in Section IV we use regression analysis to further disentangle the different relationships.

A. *Changes in the number of weeks (hours) worked by those working in 1986*

In Tables 5a and 5b we only look at workers who worked at least one week in 1986 and then turn later to those who were inactive in that year. As in Tables 3-4 we use both weeks worked and earnings as a measure of labour supply.

Table 5a

Elasticity of labour supply for workers employed in 1986— calculated from sample averages

	#obs.		$\frac{\Delta L}{L_A}$		$\frac{T}{E}$		η^E	
	male	female	male	female	male	female	male	female
All workers	4180	3346	0.143 (0.016)	0.103 (0.019)	0.157 (0.002)	0.099 (0.002)	0.91	1.04
Self-employed	812	264	0.241 (0.051)	-0.070 (0.043)	0.182 (0.006)	0.122 (0.007)	1.32	-0.57
Employed	3368	3082	0.119 (0.015)	0.118 (0.021)	0.151 (0.002)	0.097 (0.002)	0.79	1.22

Married	2535	1964	0.108	0.092	0.194	0.104	0.56	0.88
			(0.015)	(0.025)	(0.002)	(0.002)		
Single	1645	1382	0.197	0.119	0.099	0.092	1.99	1.29
			(0.033)	(0.030)	(0.003)	(0.003)		
With Children	1701	1321	0.104	0.107	0.194	0.106	0.54	1.01
			(0.013)	(0.031)	(0.003)	(0.003)		
Without Child.	2479	2025	0.169	0.101	0.135	0.093	1.25	1.09
			(0.025)	(0.025)	(0.003)	(0.003)		
Self-employed and married	613	215	0.237	-0.126	0.195	0.120	1.22	-1.05
			(0.021)	(0.049)	(0.006)	(0.007)		
Self-employed and single	199	49	0.253	0.174	0.143	0.129	1.77	1.35
			(0.199)	(0.082)	(0.014)	(0.023)		

Standard errors in parentheses.

It appears that, among workers who were already in the labour force in 1986, men increased their labour supply by more on average. However, the elasticity for women is higher because of their lower average tax rate.

Working men who received some income from self-employment in 1986 have a considerably higher elasticity of labour supply or 1.32 while the elasticity now becomes negative for women. Thus male workers with some income from self-employment responded more to tax cuts than did employees. They increased their labour supply by 24.1%, compared to the just over 14.3% increase by all men. The comparable figure for men who did not receive any income from self-employment is 11.9%. The higher elasticity for men with some income from self-employment can be caused by either a greater ability to substitute labour between years, and/or an ability to report income, earned in 1986 or 1988, in 1987 and hence evade taxes.[13]

Single men have a slightly higher elasticity of and, similarly, single women are the group of women which shows the largest positive supply response. Men without children appear to have a much stronger response than those who have children.

The main surprise here is the negative response by self-employed women. This effect turns out to be especially strong among self-employed women who are

[13] Looking at sectoral output data and the share of self-employment in employment does not reveal a relationship between the two variables. We cannot demonstrate that those sectors that rely more on self-employment have higher output growth than others. However, this may only indicate that other variables than self-employment explain most of the cross-sectoral variation in the output response.

also married as shown at the bottom of the table. While married and self-employed women reduce their supply of weeks, their single counterparts increase it.

With our earlier caveat regarding the use of earnings as a measure of labour supply in mind, we report the corresponding elasticities.

Table 5b Elasticity of total earnings for workers employed in 1986— calculated from sample averages

	#obs.		$\frac{\Delta E}{E_A}$		η_E	
	male	female	male	female	male	female
All workers	4178	3346	0.207 (0.043)	0.145 (0.015)	1.32	1.46
Self-employed	812	264	0.182 (0.017)	0.223 (0.067)	1.00	1.83
Employed	3367	3082	0.213 (0.053)	0.138 (0.016)	1.41	1.42
Married	2535	1964	0.230 (0.070)	0.161 (0.021)	1.19	1.55
Single	1644	1382	0.171 (0.015)	0.122 (0.023)	1.73	1.33
With Children	1578	1321	0.146 (0.009)	0.187 (0.030)	0.75	1.76
Without Child.	2600	1889	0.244 (0.069)	0.112 (0.015)	1.81	1.26
Self-employed and married	613	215	0.205 (0.020)	0.167 (0.046)	1.05	1.39
Self-employed and single	199	49	0.112 (0.035)	0.468 (0.302)	0.78	3.63

Standard errors in parentheses.

As in Table 5a, both single men and those without children responded more to the tax cut than did their married and employed counterparts. Comparing Tables 5a and 5b,

we see that married, self-employed women experience higher earnings but supply fewer weeks. Similarly, self-employed men now show a smaller response than employed men.

B. *Changes in labour-force participation*

We now turn to the group of workers who were inactive in 1986—that is did not work a single week in that year. In 1987, 448 workers who did not work in 1986 entered employment. At the same time, 494 workers left employment. As a result, there were 46 fewer workers employed in our sample in 1987 than in 1986. However, there were 55 more women employed in 1987 while the number of employed men in the sample fell by 101. Table 6 has the proportion of workers supplying at least one week in each of the three years—which we define as the condition for labour-force participation.

Table 6 The proportion of workers supplying at least one week of labour—sample averages

	1986		1987		1988	
	male	female	male	female	male	female
All workers	0.895	0.726	0.874	0.738	0.848	0.713
Self-employed	0.979	0.649	0.960	0.818	0.942	0.855
Employed	0.877	0.734	0.855	0.745	0.828	0.699
Married	0.911	0.706	0.893	0.750	0.885	0.731
Single	0.872	0.758	0.845	0.721	0.794	0.685
With Children	0.965	0.766	0.957	0.830	0.967	0.799
Without Children	0.858	0.699	0.829	0.674	0.784	0.652

The participation rate of men fell in all cases while that for women tended to increase. The increase was most significant for married women and those with children. However, single women and those without children had lower rates in 1987 than in 1986. In both cases, this appears as a trend which continues in 1988. The same applies to all categories of men—their employment rate was falling throughout.

IV. Worker Characteristics and the Responsiveness to Tax cuts

Table 7 analyses the supply response for individuals in three (average) tax brackets: those paying less than 20% of their earnings in taxes, those paying between 20% and 40% in taxes and those paying more than 40%.

Table 7 Taxes and the elasticity of labour supply— calculated from sample averages

	#obs.		$\frac{\Delta L}{L_A}$		$\frac{T}{E}$		$\eta_E = \frac{\Delta L / L_A}{T/E}$	
	male	female	male	female	male	female	male	female
< 20%	2807	3163	0.166 (0.021)	0. 145 (0.021)	0.091 (0.001)	0.075 (0.001)	1.82	1.93
<40%	1353	422	0.107 (0.012)	-0.042 (0.025)	0.258 (0.001)	0.249 (0.002)	0.41	-0.17
>40%	104	46	0.474 (0.275)	-0.149 (0.124)	0.600 (0.022)	0.637 (0.031)	0.79	-0.23
	#obs.		$\frac{\Delta E}{E_A}$		$\eta_E = \frac{\Delta E / E_A}{T/E}$			
	male	female	male	female	male	female		
< 20%	2834	3282	0.181 (0.032)	0.272 (0.103)	1.99	3.63		
<40%	1355	430	0.148 (0.009)	0.100 (0.017)	0.57	0.40		
>40%	108	52	0.776 (0.502)	-0.085 (0.097)	1.29	-0.13		

Standard errors in parentheses.

Looking first at men, it is clear that the largest response came from those in the highest tax group. This is the case when using both the weeks-worked and the earnings measure of labour supply. However, the elasticity is highest for the lowest tax group. The relatively large response for the lowest group can be explained by a low initial labour supply (40 weeks as opposed to 49 weeks for the group above). The converse holds for women: those women in the lowest tax group respond most, both

when measured by weeks worked and earnings. Note, in this case, the fall in weeks worked for the top two groups and also the fall in earnings for the top group.

A. *Regression analysis for the number of weeks worked (earnings)*

We have looked at both tax rates and worker characteristics and calculated simple correlation coefficients. The next step is to use regression analysis to disentangle the different determinants of the change in the supply of labour. We first look at those already supplying at least one week in 1986 and then look separately at the decision whether to supply at least one week—what we can call the labour-force participation decision.

We estimate the following equation which explains the increase in labour supply as a function of wage income (*W*) and income from self-employment (*P*), both measured in 1986 kronur:

$$L_{87} - L_A = \alpha_0 + \alpha_1 W + \alpha_2 P + \alpha_3 \tau + \mathrm{A}\tilde{x} \qquad (2)$$

We do not have data on the distribution of weeks worked between employment and self-employment and for this reason cannot calculate wage rates for the two different income variables. The variable *P* then measures the importance of income from self-employment and τ is the (average) tax rate. The second group of variables, contained in vector $\tilde{x}$, has the personal characteristics of workers: age (*a*), gender (*s*) (indexed by 1 for women), marital status (*m*) (indexed by 1 for married people) and the number of children (*c*).

The results follow first for weeks worked and then for earnings as measures of labour supply.

Table 8a Determinants of the responsiveness to tax cuts—weeks worked

Number of observations: 8,062
Method of estimation: Least-squares.
Dependent variable: $L_{87} - L_A$

variable	coefficient estimate	t-ratio
constant	8.34	5.84
Income:		
Wage income (*W*)	0.04	0.51

Income from self-empl. (P)	0.97	6.40
Characteristics:		
Gender (s)	-2.57	-5.73
age (a)	-0.30	-3.60
age-squared (a^2)	0.003	3.04
family status (m)	1.84	3.39
children (c)	-0.17	-0.68
tax rate (τ)	0.69	0.33

As before, self-employment appears to be the most important determinant of the labour-supply response. We also find that women and older workers respond by less. Single individuals now increase their labour supply by less which conflicts with Table 5a. The explanation can be found in the inclusion of the age variables which were excluded before: single individuals have a lower average age than married ones. Most importantly, and disappointingly, the (average) tax rate in 1986 is not a statistically significant determinant.

When we calculate wage rates as the ratio of total income—from both types of employment—and weeks worked and also include the ratio of wage income to income from self-employment, the results are very similar to Table 8a in that the wage-rate variable is insignificant while the variable measuring the ratio of the two kinds of income comes out positive and very significant. However, there exists a possible division bias in this case. The variable measuring the number of weeks worked in 1986 is used on both sides of the equation—on the left-hand side in the change of weeks worked and on the right-hand side in calculating the wage rate. To deal with this, we used the analogous wage rate in 1988 as instruments for the wage rate in 1986. This made the variable positive and significant while not affecting the other coefficients too much. Most importantly, the tax-rate variable did not become more significant.

When we omit all income variables from the regression, the coefficient of the tax rate becomes larger and slightly more significant (t-ratio of 1.57). Other coefficients do not change significantly. This regression compares the differential impact of the tax cut for different individuals depending on the extent of this tax cut.

We now measure the labour supply by total earnings, E.

Table 8b Determinants of the responsiveness to tax cuts—earnings

Number of observations: 8,062
Method of estimation: Least-squares.
Dependent variable: $E_{87} - E_A$

variable	coefficient estimate	t-ratio
constant	19.75	1.45
Income:		
wage income (W)	0.05	7.77
income from self-empl. (P)	0.20	13.77
Characteristics:		
Gender (s)	-27.39	-6.39
age (a)	0.99	1.22
age-squared (a^2)	-0.02	-2.07
family status (m)	10.25	1.98
children (c)	0.03	0.01
tax rate (τ)	105.2	5.24

The key difference lies in the significance of the tax-rate variable and a different dependance on age. While the youngest workers are likely to respond most in terms of weeks, they are not likely to experience the largest absolute increase in earnings. Also, for obvious reasons, high-wage workers experience larger absolute increases in earnings.

In light of Table 7, the absence of a strong relationship between weeks worked and the (average) tax rate in Table 8a comes as a surprise. We now look further at the effect of taxes. The absence of any obvious relationship between the tax rate and our two measures of labour supply is demonstrated in Figures 7 and 8 below.[14]

[14] We note that tax rates could exceed unity since taxes in 1986 were paid on income earned in 1985. So if income in 1986 was much lower than in 1985, the calculated tax rates can be very high.

Figure 7
The change in the supply of weeks and the average income tax rate in 1986 (from average of 1986 and 1988 to 1987)

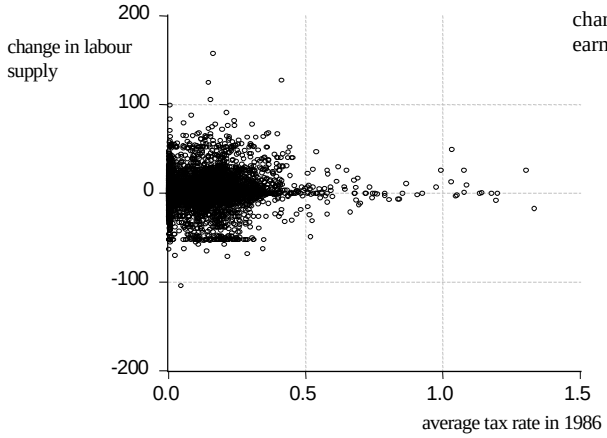
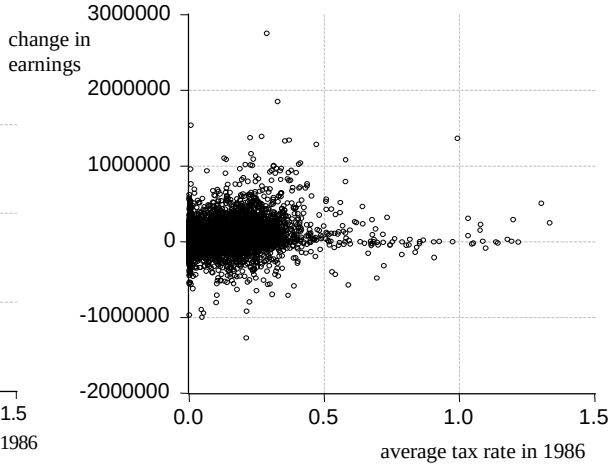


Figure 8
The change in earnings and the average income tax rate in 1986



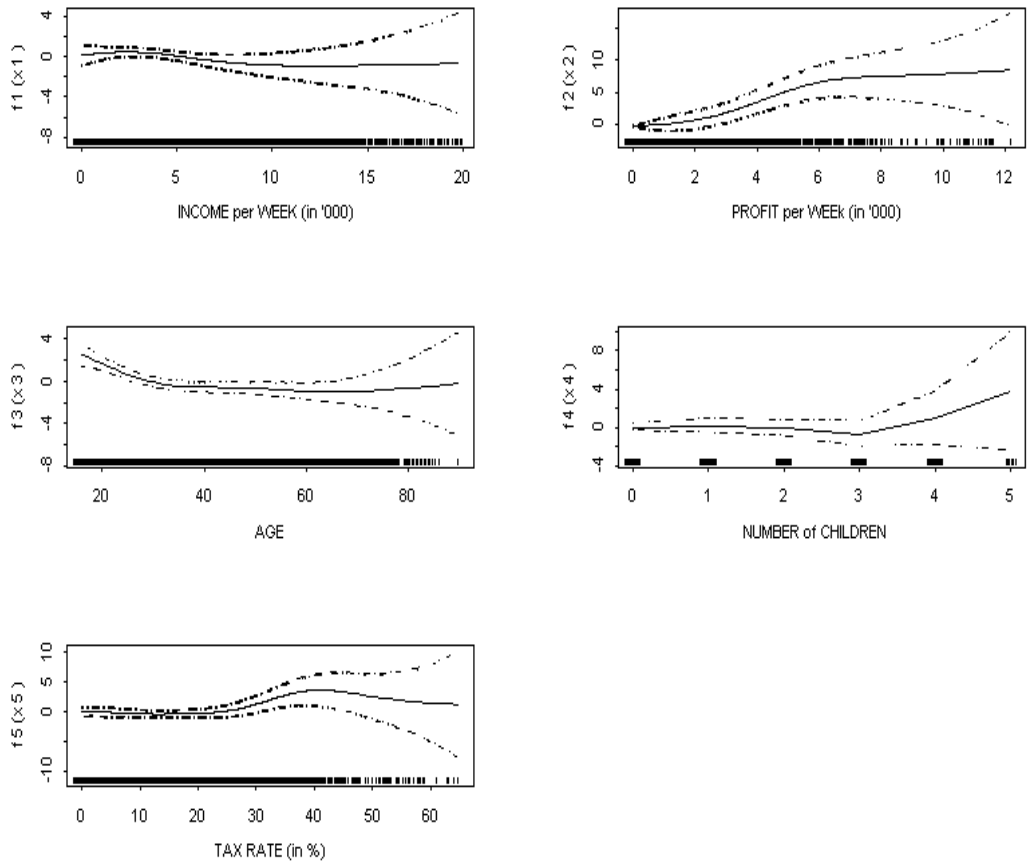
We next estimate the relationships allowing for nonlinearities. This will reveal whether the relationship between taxes and the increase in labour supply is confined to a certain range of tax rates—being absent for others. To test for nonlinearitites in equation (2), we maintain the assumption of additivity among the regressors and use a scatterplot smoother (see Hastie and Tibshirani, 1990) to estimate explicitly any nonlinearities in the relationship between the changes in labour supply and its determinants (*general-additive model* or GAM). There is no reason, a priori, to expect the relationships to be perfectly linear. The general form of the equation to be estimated is

$$\Delta L_i = f_1(w_i) + f_2(\pi_i) + f_3(s_i) + f_4(a_i) + f_5(m_i) + f_6(c_i) + f_7(t_i) + \varepsilon_i \qquad (3)$$

where the functions f can take any form and ε is a zero-mean error term.[15] The statistical results are in Figures 9 and 10 and in the appendix. Figure 9 has the results for weeks worked and Figure 10 for earnings.

[15] We describe this method in an appendix.

Figure 9 Results of GAM estimation for weeks worked

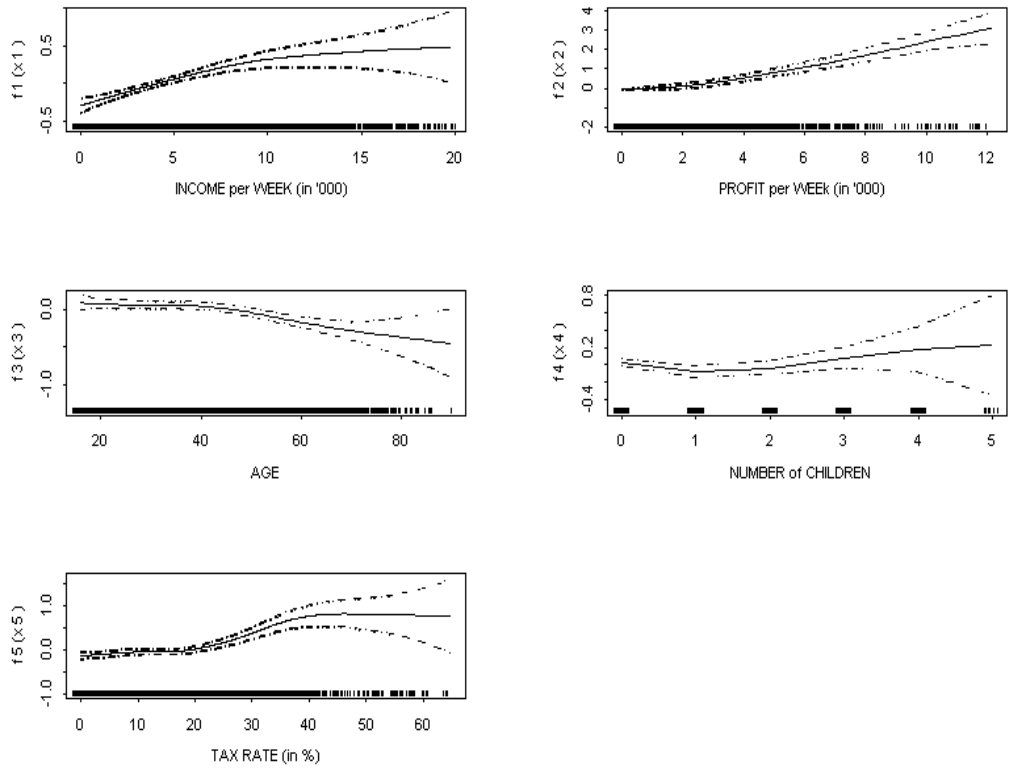


*The broken lines define the 95% confidence interval.

We now detect a relationship between the supply of weeks and the tax rate. There is a positive relationship with tax rates when these range from 20% to 40% but no relationship at lower and higher rates. This differs from Table 8a. In addition, we find that, again, the supply response is rising in income from self employment. Moreover, the response is highest for those workers under the age of 20. Looking at our results for the binary variables (not reported here), men respond by more than women and married people by more than single ones.

The important difference here lies in the tax rates where, allowing for nonlinearities, a positive relationship is apparent. Figure 10 has results when the change in earnings is used as a dependent variable.

Figure 10 Results of GAM estimation for earnings



*The broken lines define the 95% confidence interval.

These results are consistent with what we got before in Table 8b. Moreover, as in Figure 9 we have learned that the positive relationship between the tax rate and the supply response occurs in the tax range from 20% to 40%.

B. *Regression analysis for the participation decision*

Turning to the labour force participation decision, we have found that women were more likely to join the labour force than men. Below are the results of a probit regression of the following equation:

$$p = A\tilde{x} + B\, d^{87}\, \tilde{x} \qquad (4)$$

where p is a binary variable which takes the value one when a worker is employed for at least one week during the year and zero otherwise, and $\tilde{x}$ has the same variables as before: gender (s), family status (m), number of children (c) and age (a).[16] A and B are

[16] The logit estimates were qualitatively identical.

vectors of coefficients and d^{87} is a matrix of dummy variables which take the value one for the year 1987.

Table 9 Determinants of the labour-force-participation decision

Number of observations: 27,822
Estimation method: probit
Dependent variable: *p* (1 if in labour force and 0 otherwise)
Obs with *p* = 0: 5,575
Obs with *p* =1: 22,247

Variable	$\hat{a}_i$	t-ratio	$\hat{b}_i$	t-ratio
Constant	-0.430	-5.38	0.943	6.78
gender (s)	-0.142	-3.66	-0.068	-1.01
age (a)	0.118	28.07	-0.049	-6.88
age-squared (a^2)	-0.002	–35.38	0.001	6.75
family status (m)	0.391	8.31	0.034	0.42
children (c)	-0.061	-2.19	-0.011	-0.25
gender*family	-0.753	-13.08	0.134	1.36
gender*children	-0.134	-4.35	0.121	2.34

standard-error = 0.33
McFadden R-squared = 0.26
Log-likelihood = -10,257.66

We find that women were less likely to work than men, and this probability is decreasing in the number of children they have and lower for married women than single ones. Independent of gender, married people are more likely to be employed than singles and, finally, parents are less likely to be employed. When we look at the coefficient estimates in matrix B, we find that all workers were more likely to participate in 1987, independent of attribute. Also, that younger workers are more likely to participate in 1987 than in the other two years in the sample and finally that married women with children were more likely to work in 1987.

V. Effect on the Density of Labour Supply and Wages

The question remains what was the effect of the tax-free year on the distribution of labour supply and—more importantly—income. We estimate the density function for labour using kernel-density estimation (see Silverman, 1986; Härdle, 1990). The estimated densities are shown in Figures 11-14. Figures 11 and 12 show the densities

for average weeks and earnings in 1986 and 1988—our baseline—while Figures 13 and 14 show the densities for labour supplied in 1987.

In Figures 11 and 13 we find the density to have three modes in the baseline: one mode at zero weeks, another around 25 weeks, and the third at 52 weeks. The last one dominates the first two. The three models correspond to respectively nonparticipation, part-time work and full-time work. But we also note that some workers work in excess of 52 weeks a year. This is due to multiple jobs, or part-time self-employment by employed workers.

In 1987, the centre of the distribution falls down—this applies to both the part-time mode and the full-time mode—while the right-hand tail becomes fatter. It is of interest to note that a significant proportion of the increase in labour supply takes the form of previously full-time workers taking on additional work, instead of only part-time workers going full time.

Figures 12 and 14 show the analogous densities when labour supply is measured by earnings—the sum of wage income and income from self employment. In Figure 12 we show the density for average earnings in 1986 and 1988. This has two models, one of which corresponds to nonparticipation. The density of earnings for those employed is hence unimodal. In Figure 14 we then show the density for earnings in 1987. The mode shifts to the right and higher levels of earning are now more frequently observed.

Figure 11
Distribution of weeks supplied in 1986 and 1988

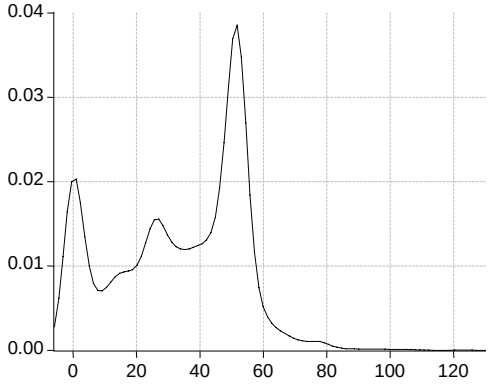


Figure 12
Distribution of earnings in 1986 and 1988

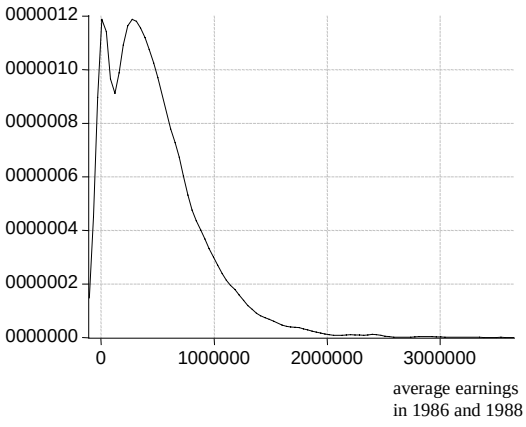


Figure 13
Distribution of weeks supplied in 1987

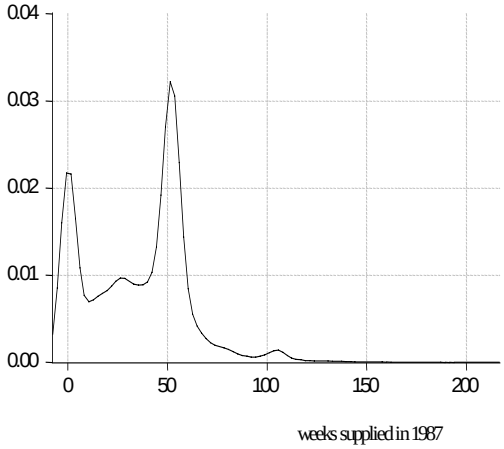
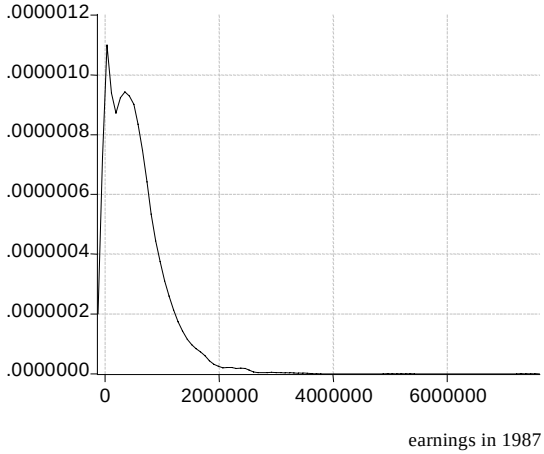


Figure
Distribution of earnings in 1987



We note that the standard deviation of labour supply in our sample has increased in both cases. It goes up by around 18% in the case of earnings (from 409,436.4 to 481,715.8) and by around 26% in the case of weeks worked (from 20.5 to 25.9). In light of the unimodal earnings distribution, the variance is a good measure of the dispersion of earnings. Its increase suggests that the tax cut widened the earnings distribution.

VI. Conclusions

We have looked at the response of labour supply during the tax-free year in Iceland in 1987 using a sample of 9,274 workers out of a total of 180,577 in that year. We take the observed increase in labour supply to be an upper bound on the effect of tax cuts for three reasons: First, tax rates were brought down to zero. Second, (marginal) tax rates were reduced for only one year and during this one year taxes were still paid (that is on income earned in 1986). For both reasons, the income effect of the tax cut was reduced while the substitution effect remained intact. Third, the economy was booming because of other factors which could be expected to raise labour supply through higher wages. Our observations can be summarised as follows:

- There is a large variation across individuals in their labour-supply response. Some workers (2,455) decided to work less in 1987 while others (3,860) decided to work more.

- When averaging across the whole sample, the elasticities of labour supply fall close to those reported by Killingsworth (1983) for American workers. The elasticity of weeks worked to the rise in after-tax wages was 0.26 for all workers, 0.41 for men, and 0.11 for women when looking at all workers—both those who were employed in 1986 and those who decided to join in 1987. The elasticity of earnings was 0.61 for men and 0.72 for women with an average of 0.67. The higher elasticity using earnings is partly explained by an increase in real wages.

- Looking only at workers who were employed in 1986, men responded more than women. Men who received some income from self-employment in 1986 had a considerably higher elasticity of labour and increased their labour supply by 24.1%, compared to the 14.3% increase by all men. Single men also had a slightly higher elasticity. Similarly, single women were the group of women that showed the largest positive supply response.

- The increase in labour supply during the tax-free year—measured either by the number of weeks worked or earnings—is a positive function of the tax rate in previous year for tax rates between 20% and 40% but independent of the tax rate outside of this range.

- The participation rate for men in our sample fell in all cases while that for women tended to increase. The increase was most significant for young workers and married women.

- The density of (gross) earnings has one mode (if we omit workers not in employment) while the density of weeks worked has two—corresponding to part-time and full-time work. In 1987, the frequency of higher earnings and weeks worked increased significantly and, most importantly, the variance of the earnings distribution increased significantly.

Appendix

A1 Generalised additive models

In the classical linear-regression model, a dependent variable y (response) is linearly related to a set of p independent variables X_1, X_2, … X_p (predictors) according to the equation

$$y = \alpha + X_1\beta_1 + X_2\beta_2 + ... + X_p\beta_p + error$$

where y, X_1, X_2, …, X_p are column vectors of length n—the number of observations in the sample. Generalized additive models (GAM) generalise the classical linear-regression by replacing the linear functions in the equation with generic functions $f_i(X_i)$, for i =1,…, p, according to the model

$$y = \alpha + f_1(X_1) + f_2(X_2) + ... + f_p(X_p) + error\,.$$

Such functions are not restricted *a-priori* to be linear, quadratic, etc. but are rather nonparametrically estimated from the data using the so called back-fitting algorithm of Hastie and Tibshirani (1990).

The fit of a GAM model is based on the idea of scatterplot smoothing, using nonparametric smoothers such as smoothing splines or locally weighted scatterplot smoothers. Hastie and Tibshirani (1990) describe these smoothers in detail, showing how the degree of smoothing in the fitting of a GAM model is governed by a smoothing parameter called "degrees of freedom" (*df*); this is defined as the trace of a smoothing matrix of weights which is applied to the response y to obtain a nonparametric estimate of the i-th function $f_i(X_i)$.

In the classical linear regression model, the smoothing matrix is given by $S_{ols} = (X'X)^{-1}X'$ (producing $\hat{y} = Sy$) and the degrees of freedom is simply the number of predictors, i.e. $df_{ols} = p$. There is therefore a clear analogy with the classical linear regression model, which gives the degrees of freedom of a GAM model an appealing intuitive interpretation as the number of parameters used to fit the data (the larger this number the less smooth the corresponding estimated function). Exploiting this analogy, Hastie and Tibshirani (1990) also show how nonparametric test statistics can be developed to evaluate the significance of various predictors, as well as the statistical significance of nonlinearities in the $f(X)$ functions, which parallel standard F-tests (likelihood ratio tests) of the classical linear regression model.

Turning to our equation (3), the results presented in the tables below show the importance of the nonlinear component for various predictors in our first regression by means of nonparametric F-test statistics (Npar-F) and associated p-values, Pr(F). It appears from the table that all functions f_2 to f_5 are significantly different from the linear functions at the 10% level. Function f_1 is not significant at 10% level though its p-value is close to 0.10.

Results for regression using weeks supplied.

	df	Npar-F	Pr(F)
Intercept	1.0		
f_1(W)	3.0	2.113225	0.1208671
f_2(P)	3.0	2.720495	0.0658588
f_3(a)	3.0	5.240321	0.0053108
f_4(c)	3.0	2.593140	0.0748218
f_5(t)	4.7	3.311247	0.0122905
f_6(m)	1.0		
f_7(s)	1.0		

Results for regression using earnings.

	df	Npar-F	Pr(F)
Intercept	1.0		
f_1(W)	2.0	3.466978	0.03121841
f_2(P)	2.0	8.154256	0.00028870
f_3(a)	2.0	8.154256	0.00028870
f_4(c)	2.0	4.343230	0.01301281
f_5(t)	3.7	6.927142	0.00002722
f_6(m)	1.0		
f_7(s)	1.0		

A2 An Intertemporal Model of Labour Supply

A closed-economy version of the Ramsey model can be used to show the effect of a tax cut similar to that implemented in Iceland. The choice of a closed-economy model is justified in light of the severe restrictions on capital movements that were in place in Iceland at the end of the 1980s.

The representative agent chooses his consumption *C* (saving) and labour supply *L* to maximise the present discounted value of future utility:

$$\underset{C,L}{Max} \int_0^{\infty} u(C_t) e^{-\theta t} dt \qquad \text{(A1)}$$

subject to;

$$\dot{K} = rK + \left(1-\tau\right)wL - C + Z - \delta K \qquad \text{(A2)}$$

K denotes the stock of capital, *r* is the rate of interest and the rental on capital, τ is the tax rate, and *Z* denotes transfers from the government—which can be negative in case of non-income related taxation.

This gives the following (current-value) Hamiltonian function:

$$H = u\left(C_t, L_t\right) e^{-\theta t} + \lambda_t \left[rK + \left(1-\tau\right)wL + Z - \delta K_t - C_t\right] \qquad \text{(A3)}$$

where λ is the current-value costate variable. The first-order conditions follow:

$$u_C = \lambda_t \tag{A4}$$

$$u_L = -\lambda_t w(1-\tau) \tag{A5}$$

Combining equations (A4) and (A5) gives,

$$-u_L = u_C w(1-\tau). \tag{A6}$$

This is equation (1) in the text. The left-hand side has the marginal cost of increasing labour supply while the right-hand side has the marginal benefit. The marginal cost is the disutility of increased work while the marginal benefit is the utility of the increased consumption thus made possible. From equation (A6) we can see that when the capital stock rises, raising wages and the marginal product of labour, this should increase the supply of labour. This is the substitution effect. But the shadow price of capital is decreased as the marginal product of capital falls and this reduces the supply of labour. This is the income effect. The net effect is ambiguous.

The following condition has the shadow price of wealth (capital) which is the (current-value) costate variable λ.

$$\frac{\dot{\lambda}}{\lambda} = \theta - [r - \delta] \tag{A7}$$

The shadow price depends on the rate of pure time preference θ, the real rate of interest and the rate of depreciation δ. Combining equations (A4) and (A7) gives,

$$\theta - \frac{\dot{u}_C}{u_C} = r - \delta \tag{A8}$$

which determines optimal consumption and saving at each point in time. The left-hand side is the marginal cost of saving and the right-hand side the marginal benefit. The marginal benefit is equal to the net marginal product of capital while the marginal cost is the sum of the rate of pure time preference and the negative of the rate of change of marginal utility of consumption.

Factor-market equilibrium is characterised by the following equations:

$$F_L(K, L) = w, \qquad F_K(K, L) = r \tag{A9}$$

We now assume the following form for the utility and production functions:

$$u(C_t, L_t) = \frac{C^{1-\gamma}}{1-\gamma} - \frac{1}{\beta} L^{\beta}, \qquad F(K_t, L_t) = AK_t^{1-\alpha} L_t^{\alpha} \tag{A10}$$

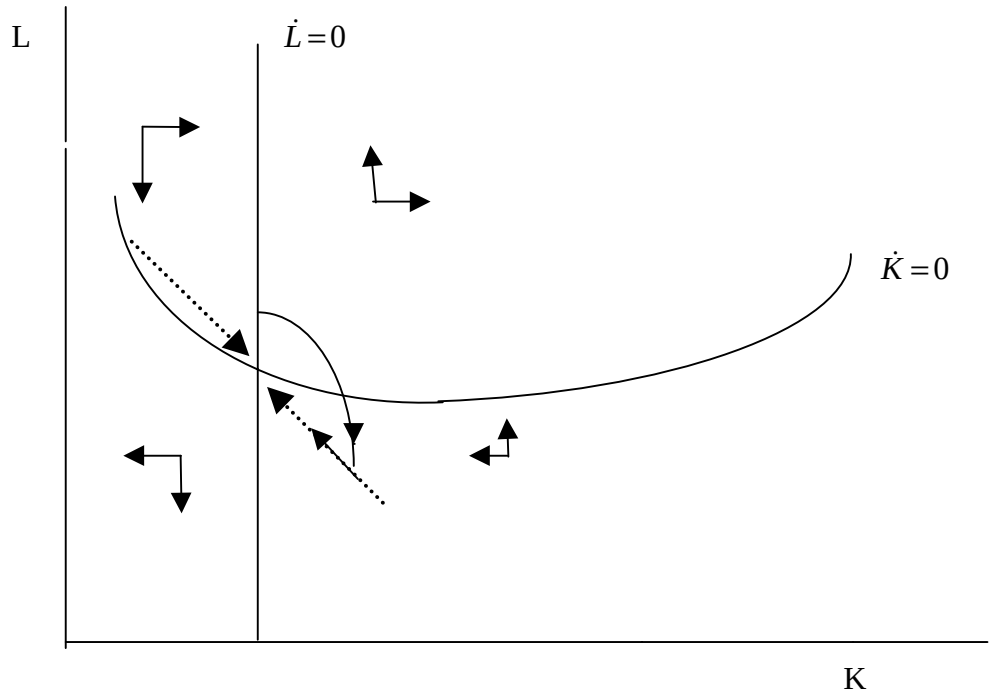
Equations (A7), (A8), (A9) and (A10) give;

$$\frac{\dot{C}}{C} = \frac{1}{\gamma}[F_K(K_t, L_t) - \delta] \tag{A11}$$

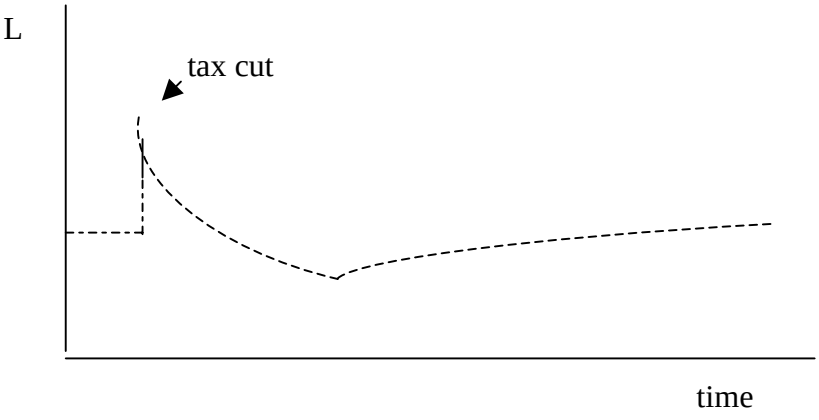
and from equations (A5), (A7), (A9) and (A10) we get;

$$\frac{\dot{L}}{L} = \left(\frac{\sigma_L F_L(1-\tau)}{1+\varepsilon_{F_L, L} F_L(1-\tau)\sigma_L} \right) [F_K(K, L) - \delta - \theta] \tag{A12}$$

where σ_L is the pure elasticity of intertemporal substitution $u_L/(u_{LL}L)$, and $\varepsilon_{F_L,L}$ is the elasticity of the marginal product of labour F_L with respect to employment. From equation (A10) we find that $\sigma_L = 1/\beta - 1$, $\varepsilon_{F_L,L} = \alpha - 1$ and $F_L = \alpha A\left(\frac{K}{L}\right)^{1-\alpha}$. The solution is described in the following phase diagram.



The tax on wage income τ is now cut to zero for a moment, but lump-sum taxes raised leaving total taxation unchanged; $(d\tau)L = dZ$. This leaves the $\dot{K}=0$ locus unaffected. Labour supply increases transitorily and we move down to the old saddle path with falling labour supply, rising capital and falling interest rates. We then move up the saddle path to the unchanged steady state with rising labour supply and a falling capital stock. The path of labour supply is shown in the figure below.



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