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Modelling farmers' labour supply in CGE models

by

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Abstract

In most CGE models with special focus on farm policy, the on-farm wage either follows the ordinary wage in the economy or it is varies according to an assumption of sector specific farm labour. This paper demonstrates a practical and empirical consistent way to model farm household allocation of labour in CGE models, assuming that farm labour is partially sector specific. In this set up, preferences for farming and the relative wage between on-farm and off-farm work, determines the allocation of farm household labour between on-farm and off-farm work. Reallocation of labour as a response to change in relative wage, is assumed to be sluggish.

Using the Norwegian agricultural sector as a case, the paper demonstrates clearly that the farmers' preferences for on-farm work are of vital importance as to how a liberalisation of farm policy affects farm output and farmers' income. The results depend on technology; i.e. to what degree costs can be reduced by replacing hired labour, capital and other factors with cheaper family labour. Technology is especially important when preferences for on-farm work are high, i.e. when farmers accept to work at their own farm even if the wage falls substantially.

1. Introduction

According to Gardner (1992) income differences in the United States between farmers and the rest of the population have disappeared gradually over the last forty years. However, in Europe there is evidence that on-farm wages are significantly below off-farm wages. This conclusion follows both from French farm household micro data (Fall and Magnac, 2004) and from dairy farm data in the Netherlands (Elhorts, 1994).

Why farmers, in spite of this, allocate labour to the farm, is commonly explained by strong preferences for farming or various social commitments to the farm. Thus, there are some non-monetary factors or personal satisfaction reasons to work on own farm. Tastes for farming seem to be larger for males and they also tend to be heterogeneous according to education and age (Falls and Magnac, 2004).

However, even at competitive farm wages there are arguments for off-farm work. An economic argument is risk diversification since farm income tends to vary more than off-farm income. Social contact afforded by off-farm work is another argument, emphasized by Nolan (1994) and Taylor and Little (1995). Also, off-farm work can be due to differences in tastes and skills between members of each household.

When modelling agricultural policy it is crucial that preferences for farming are represented in a proper way. An exogenous on-farm wage, as is often assumed in partial equilibrium models, tends to overestimate the negative effect on farm activity when farm profitability declines. In computational general equilibrium (CGE) models with special focus on farm policy, the wage is *per se* endogenously, but most often the farm wage either follows the ordinary wage in the economy or it is varies according to an assumption of sector specific farm labour. The latter rests on the assumption that farm labour can not be reallocated to other industries in a short or medium time perspective.

A more realistic assumption is that farm labour is *partially* sector specific; i.e. that the farm household, dependent on relative wage and preferences, allocates its working time between on-farm and off-farm work, respectively, and that the household's reallocation of labour as a response to change in relative wage, is sluggish. Using the Norwegian agricultural sector as a case, this paper demonstrates a practical and empirical consistent way to model farm household allocation of labour in CGE models.

Section 2 gives estimates of the relative wage between on-farm and off-farm work. Time spent on on-farm work and off-farm work at this relative wage is reported. From this information, the on-farm share of the farm households' total wage income is deduced. A modelling approach using a Constant Elasticity of Transformation (CET) function is then presented in Section 3. One point on this function is available from the figures in Section 2. The household's preferences for on-farm work are related to the curvature of the CET function, determined by the transformation elasticity. For different values of this elasticity, impacts on labour allocation and income of a change in relative wage are reported. To assess what seems to be a reasonable assumption as to the transformation elasticity, the corresponding on-farm labour supply elasticitiy is computed for each equilibrium.

Finally, in Section 4, an aggregated CGE model is employed to demonstrate how farm household preferences affect the results in CGE analysis of agricultural policy. In the model simulations, consideration is also given to production technology. Production technology matters because lower farm profitability change relative input prices in favour of sector specific family labour. Dependent on technology, a change in relative input prices opens for input substitution. Cost can be reduced by replacing hired labour, capital and other factors with cheaper family labour. This will affect both production and pay off from the farm, with repercussions on the on-farm wage.

2. Farm household labour supply

The average on-farm wage income in the Norwegian agriculture for the year 1997 was about NOK 100,000 per man-year, or NOK 53 per hour work, while the average wage for workers in manufacturing industries were NOK 119 per hour work. If we consider the manufacturing industries to be the farmers' alternative option for employment, then the relative wage between on-farm and off-farm work is 0.45. At this relative wage the average farm household allocates labour to its own farm and other industries with the shares 0.47 and 0.53, respectively, and only 29 % of the household's total wage income comes from on-farm work.

The upper line in Figure 1 indicates that the average on-farm wage income has fluctuated around a relative stable level over time. Also, the share of household labour allocated to own farm has been stable, as can be seen from the lower line. Consequently, the figures in 1997 are quite representative. Even in the longer term the farm households seem to accept a sub-market return on family labour. This is in line with the findings for French and Dutch farm households, mentioned in the introduction.

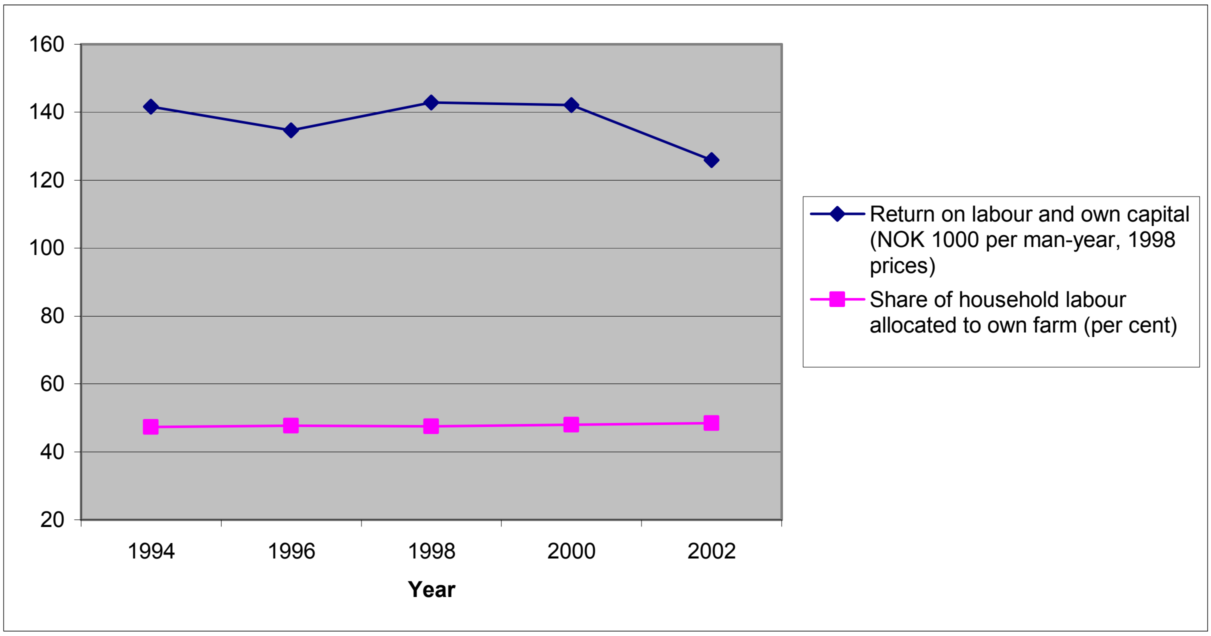

Figure 1. Return on labour and own capital and share of household labour allocated to the farm. Period 1994-2002.

The on-farm wage and the share of labour allocated to own farm differ between holdings, especially with respect to scale and type of production. Off-farm work is most common at small farms where the household labour endowment exceeds the requirement at the farm. Also, sheep and grain farmers work more off-farm than milk farmers, mainly because the demand for labour is more seasonal in these productions. The on-farm wage is, typically, negatively correlated to the share of off-farm work. A likely explanation is that a substantial off-farm income is necessary when the on-farm wage is low, and *visa versa*.

3. A Modelling Approach

A farm household allocates its labour between agriculture (family labour, F) and other industries (off-farm labour, L). The allocation can be modelled by a Constant Elasticity of Transformation (CET) function:

$$Q = \left[\sum_{i=F,L} a_i Z_i^{\rho} \right]^{1/\rho} = 1. \tag{1}$$

$a_i > 0$ (i = F,L) are distribution parameters, and Z_i are labour allocated to agriculture and other industries, respectively. ρ is the transformation parameter, defined as $\rho = (\sigma-1)/\sigma$, where $\sigma < 0$ is the constant transformation elasticity between Z_F and Z_L. The level of available labour resources, Q, is, for simplicity, normalized to 1.

If we have an estimate of the transformation elasticity, then the distribution parameters can be calibrated from the observed allocation of labour in a representative base year. The distribution parameters follow from:

$$a_i = \alpha_i^0 \left(1 / Z_i^0\right)^{\rho}. \tag{2}$$

The top script 0 refers to the base year. α_i^0 is the base year share of total wage income from source *i* (i = F,L), defined as:

$$\alpha_i^0 = \frac{w_i^0 Z_i^0}{\sum_{j=F,L} w_j^0 Z_j^0} \tag{3}$$

How labour is allocated according to this function, is illustrated in Figure 2. Assume that the off-farm wage, w_L, is exogenously given, and normalized to 1. The payoff on the farm is less than half of this, i.e. $w_F = 0.45$. Thus, the relative wage between on-farm and off-farm work is: $w = w_F/w_L = 0.45$. At this relative wage the household allocates labour to its own farm and other industries with the shares 0.47 and 0.53, respectively, and only 29 % of the household's total wage income comes from on-farm work. Point B in the figure is in accordance with this observed fact.

Let us now assume a transformation elasticity, σ , equal to -3. In point B, σ = -3 corresponds with a on-farm labour supply elasticity, ε, equal to 1.6. This follows from:

$$\varepsilon = -\sigma + \sigma\theta \ , \tag{4}$$

where θ is the share of labour allocated to agriculture. Thus, the CET frontier passes through B with the curvature in the figure.

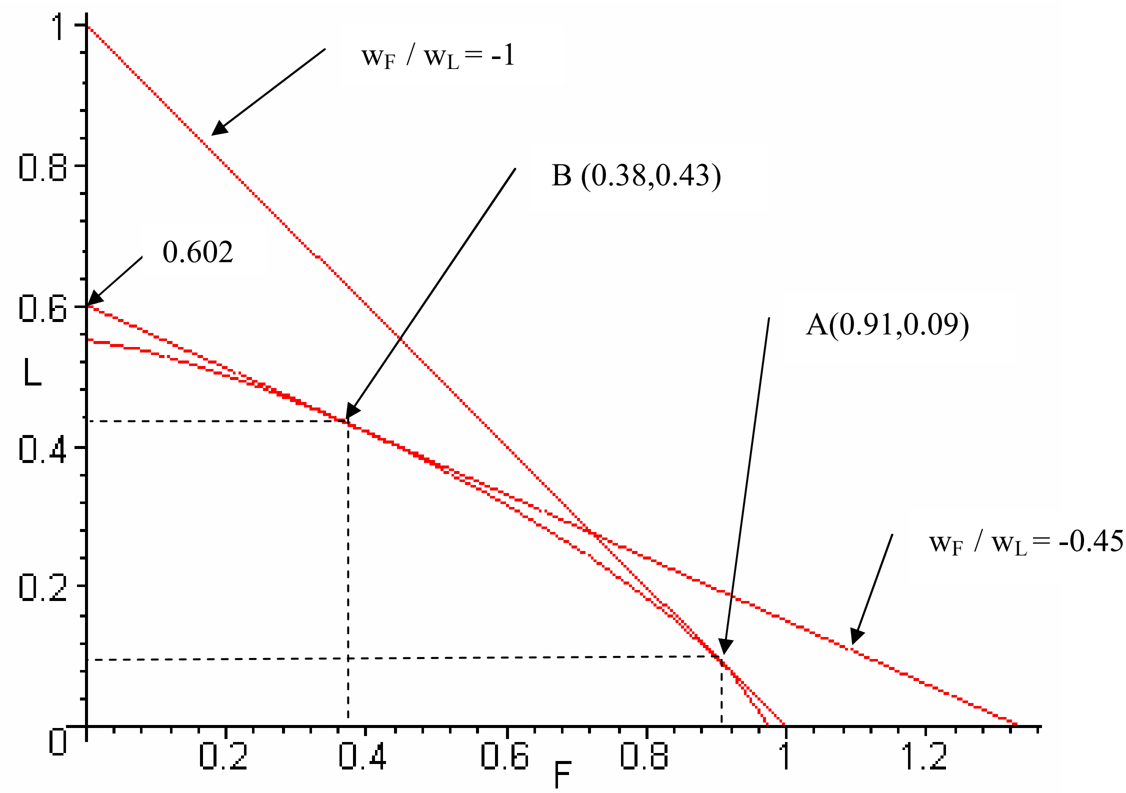

Figure 2. Allocation of labour between own farm (F) and other industries (L).

Point A is the equilibrium that would occur if the farm was able to match the normal wage in the economy, i.e. w_F = 1. Compared to the present situation (point B), it is reasonable to believe that the farm household would like to allocate far more of its labour to the farm. Due to the low farm wage, however, off-farm income is necessary. Thus, one can expect that the share of labour allocated to agriculture is high in point A. However, it is not likely that it is 1 since qualifications and preferences for work differ between members of a farm household. Correspondingly, the on-farm labour supply elasticity is expected to be quite low at point A.

From the figure it follows that the farm household in point A would allocate 91% of its labour to the farm, and on-farm wage income would constitute the same percentage of total wage income. According to expression (4), the on-farm labour supply elasticity, ε, is 0.28 in point A, i.e. far lower than in point B.

The household's preferences for on-farm work are related to the curvature of the CET function. Note that labour supply ($Z_F + Z_L$) reaches its maximum at point A, where the transformation frontier tangents the 45°line. Every movement away from point A entail costs, or loss in income. Obviously, the preferences for on-farm work are stronger the more concave the function is. For example, if w_F declines from 1, i.e. as we move north-west along the curve from point A, a one unit decline in on-farm work results in a less than one, and declining, increase in off-farm work. Correspondingly, if w_F rise from 1, a one unit increase in on-farm work leads to a higher than one decrease in off-farm work.

If the transformation elasticity approaches infinity ($\sigma \rightarrow -\infty$), the farm household has no special preferences for on-farm work. A decrease in on-farm wage, will in this case have no effect on total wage income since the labour can be transferred without costs to the alternative labour market. If other agricultural inputs are perfectly mobile too, the agricultural sector will be wiped out.

If the transformation elasticity is equal to -3, as in Figure 2, we see that on-farm labour effort falls by 58 % when on-farm wage declines from 1 to 0.45. Relatively more labour is thus allocated to off-farm work, but, compared to point A, note that about 20 % of the labour simply evaporates. The value of this labour, in terms of lost income or economic welfare, represents the preferences from staying in agriculture. From the intersection of the 45°line and the vertical axis, we see that the farm household is willing to accept a 40 % decrease in total wage income to keep up 42% of its labour at the farm.

Compared to the base solution (w = 0.45), Table 1 reports effects on labour allocation and income from a lower (w = 0.225) and higher (w = 1) relative wage, respectively, under different assumptions about the transformation elasticity (σ=-1, σ=-3 and σ=-9). The last row provides the corresponding on-farm labour supply elasticities.

Table 1. The importance of relative wage on labour allocation and income: sensitivity with respect to transformation elasticity.

	Lower on-farm wage (w = 0.225)			Base solution (w = 0.45)			Higher on-farm wage (w = 1)		
	$\alpha = -1$	$\alpha = -3$	$\alpha = -9$	$\alpha = -1$	$\alpha = -3$	$\alpha = -9$	$\alpha = -1$	$\alpha = -3$	$\alpha = -9$
Labour supply	0.86	0.74	0.72		1		1.08	1.23	1.453
On-farm	0.27	0.07	0.00		0.47		0.72	1.12	1.452
Off-farm	0.60	0.67	0.72		0.53		0.36	0.12	0.001
Labour inncome	0.66	0.69	0.72		0.74		1.08	1.23	1.453
On-farm	0.06	0.02	0.00		0.21		0.72	1.12	1.452
Off-farm	0.60	0.67	0.72		0.53		0.36	0.12	0.001
On-farm labor supply elasticity	0.69	2.70	8.98	0.53	1.59	4.77	0.34	0.28	0.008

The referred points from Figure 2 are found in the table as Column 4 (Point B) and Column 6 (Point A). We see that a 50 % cut in on-farm pay off (compared to the base solution), implies a strong reduction in on-farm labour supply, especially when the preferences for farming is assumed to be relatively low (α = - 9). Total labour income is, however, only moderately affected as the farmers transfer more of their effort to the higher paid alternative labour market. When preferences for farming is low (α = - 9), income is mainly unaltered, while income decreases by 10 % when preferences are assumed to be high (α = - 1). In the medium case (α = - 1), the farm household is willing to accept a 7 % decrease in income to sustain 15 % of the base line level of on-farm work.

4. CGE analysis

To demonstrate this modelling approach for farmers' labour allocation, we apply a highly aggregated numerical CGE model. In the model simulations, consideration is also given to production technology. Production technology matters because lower farm profitability change relative input prices in favour of sector specific family labour. Dependent on technology, a change in relative input prices opens for input substitution. Cost can be reduced by replacing hired labour, capital and other factors with cheaper family labour. This will affect both production and pay off from the farm, and give repercussions on the on-farm wage.

The model includes production sectors for agriculture, food processing and the rest of the economy. On the demand side there is a representative household who consumes 2 consumption goods – food and other goods. A public sector collects taxes and levies and disburses subsidies and transfers. The public budget is balanced by the endogenous level of transfers from the public sector to the private household. The trade balance is fixed to the base year level, and the model has an endogenous rate of exchange.

Table 2. Social accounting matrix for Norway (1997) (million NOK).

	Production sectors			**Trade**		**Consumer sectors**		
	Agriculture	Food processing	Other	Import	Export	Private household	Public sector	**TOTAL**
Agricultural goods	14 977	-14 977						0
Processed food	6 378	34 189	-8 591	6 926	-2 615	-37 546	1 259	0
Other goods	-12 363	-7 506	1 020 291	374 398	-445 466	-397 813	-531 541	0
Labour	-7 385	-6 890	-446 661			460 936		0
Capital	-10 924	-3 038	-406 620				420 582	0
Net subsidies	9 317	-1 778	-158 419	-15 175		-59 718	225 773	0
Foreign currency				-366 149	448 081		-81 932	0
Transfers						34 141	-34 141	0
TOTAL	0	0	0	0	0	0	0	0

A consistent social accounting matrix using National Account Data for 1997, is presented in Table 2. A positive entry signifies a revenue, while a negative number is an expenditure. Observe that all row and column sums are zeros, which means that supply equals demand for all commodities, no production sector has extraordinary profit, and the households exhaust all their revenues on consumption, saving and transfers. Note that agriculture only constitutes a marginal part of the Norwegian economy, as the gross product is below 1% of GDP. Agricultural support is very high, both in the form of subsidies (9.3 billion NOK) and import barriers (estimated to about 8 billion NOK, see OECD, 2003).

In the simulations we cut the farm gate price of agricultural products by 10%[1]. Preferences are represented by 3 assumptions with regard to the transformation elasticity value, namely $\sigma = -1$, $\sigma = -3$ and $\sigma = -9$. The first of these represents dedicated farmers, as opposed to the latter where preferences for on-farm work are weak. The middle alternative is a best guess based on Section 3.

The production technology is represented by a CES production function with input nesting as indicated in Figure 3. Agricultural goods are produced with input of labour, capital and goods, which can substitute for each other in accordance with an elasticity of substitution equal to σ_1. Labour is an aggregate of family effort and hired work. The elasticity of substitution between these two sources of labour is given by σ_2. Cost shares for the inputs in each nest are added in parenthesis. With regard to the elasticities of substitution, 3 different assumptions are applied: Leontief technology ($\sigma_1 = \sigma_2 = 0$), best guess ($\sigma_1 = 1$, $\sigma_2 = 2$) and high flexibility ($\sigma_1 = \sigma_2 = 9$).

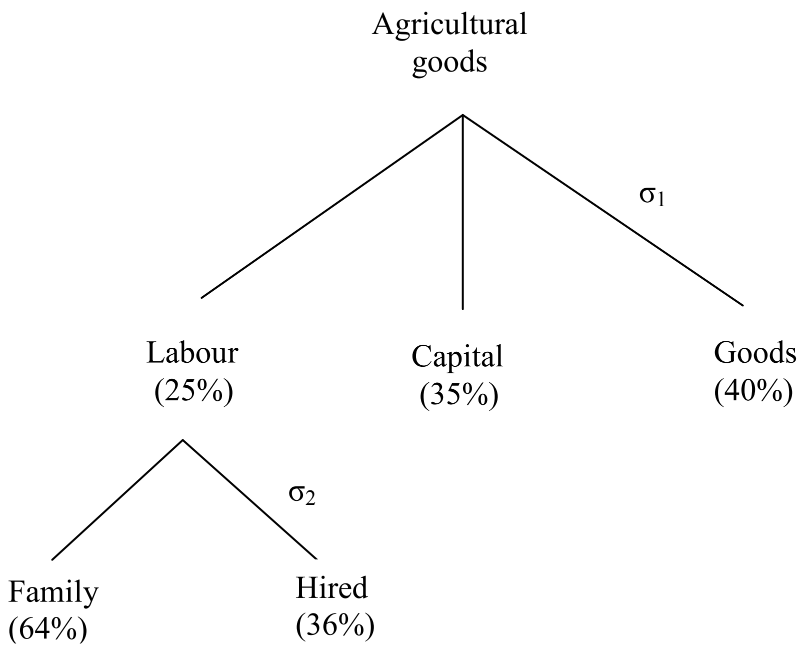

Figure 3. Production technology at farm level

[1] The farm gate prices are lowered by cutting the import tariffs.

Table 3. Effects of a 10% decrease in farm gate price

		Strong preferences[1]			Best guess preferences[2]			Weak preferences[3]		
	Base solution	Leontief tech.[4]	Best guess tech.[5]	Flexible tech.[6]	Leontief tech.[4]	Best guess tech.[5]	Flexible tech.[6]	Leontief tech.[4]	Best guess tech.[5]	Flexible tech.[6]
Production	1	0.50	0.35	0.19	0.13	0.14	0.11	≈0	0.01	0.02
Input factors										
Capital	1	0.50	0.32	0.09	0.13	0.13	0.06	≈0	0.01	0.01
Hired labour	1	0.50	0.22	0.07	0.13	0.09	0.05	≈0	0.01	0.01
Family labour	1	0.50	0.65	0.81	0.13	0.26	0.53	≈0	0.01	0.12
Other goods	1	0.50	0.32	0.08	0.13	0.13	0.06	≈0	0.01	0.01
Wage (weighted average)	0.74	0.78	0.76	0.74	0.95	0.90	0.82	1.01	1.01	0.96
On-farm	0.45	0.20	0.26	0.35	0.21	0.27	0.35	0.20	0.27	0.35
Off-farm	1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Labour supply	1	0.84	0.89	0.95	0.73	0.78	0.87	0.71	0.72	0.75
On-farm	0.47	0.24	0.30	0.39	0.06	0.12	0.25	≈0	0.01	0.06
Off-farm	0.53	0.60	0.59	0.56	0.67	0.66	0.61	0.71	0.71	0.69
Labour income	1	0.88	0.91	0.95	0.93	0.95	0.96	0.97	0.97	0.98
On-farm	0.29	0.06	0.11	0.18	0.02	0.05	0.12	≈0	≈0	0.03
Off-farm	0.71	0.82	0.80	0.77	0.91	0.90	0.84	≈97	0.97	0.95

[1] $\sigma = -1$. [2] $\sigma = -3$. [3] $\sigma = -9$.
[4] $\sigma_1 = \sigma_2 = 0$. [5] $\sigma_1 = 1, \sigma_2 = 2$. [6] $\sigma_1 = \sigma_2 = 9$.

Table 3 gives the results from the different simulations. The first column is the base solution which replicates the social accounting matrix in Table 2 as well as the actual on-farm wage and farm household labour supply and income accounted for in Section 2. Total labour supply and income, and production and input levels are normalized to 1.

First of all, the results demonstrate clearly that the farmers' preferences for on-farm work are of vital importance as to how declining farm profitability affects farm output and farmers' income. In the best guess scenario with regard to technology, the decrease in production varies between 35 % and 99 %, dependent on the size of the transformation elasticity. When preferences for on-farm work are assumed to be strong (σ = -1), the farm household keeps about 1/3 of its total labour effort at the farm even at a pay off that is 75 % below the alternative market wage. This makes it is possible to sustain 35 % of the production. On the other hand, when preferences for on-farm work are weak, represented by σ = -9, farmers direct most of its working capacity to other industries (99 %). Consequently, agricultural production is almost wiped out (-99 %).

Naturally, lower farm profitability has a negative impact on farmers' economic welfare. Farm household labour income is an indicator of economic welfare. As can be seen from Table 3, when σ = -9, total labour income is only slightly affected (-3 %), but when σ = -1, income falls by 9 %. So when farmers are dedicated to the farm, lower farm profitability means a relatively high loss in utility. Farmers with weak preferences for on-farm work, however, are not so much affected since they switch to better paid off-farm work at relatively low costs.

As a response to lower profitability, agriculture demands less input factors. Family labour, that is partially sector specific, is the only input that responds to lower demand in the form of a lower price. Dependent on technology, this opens for input substitution. Cost can be reduced by replacing hired labour, capital and other factors with cheaper family labour. The results show that technology first of all matters when preferences for on-farm work are high, i.e. when farmers accept to work at their own farm even if the wage falls substantially. When inputs are used in more or less fixed proportions, costs can hardly be reduced through substitution. Therefore, as long as the payoff from on-farm work is positive, production will be high and on-farm wage low.[2] On the contrary, if flexibility is high, agriculture can reduce

[2] In the extremity with Leontief technology combined with a transformation elasticity equal to 0, production will be unaltered until on-farm wage falls to 0. Then production will be closed down.

costs by lowering the levels of hired labour, capital and other factors relative to family labour. Then, production drops substantially, but the payoff to the farmer sustains at a relatively high level.

However, when preferences for on-farm work are weak, technology hardly affects production and income levels. In this case, it is difficult to achieve cost reductions through input substitution, independent of technology. The reason is that farm households direct most of its working capacity to other industries, and not as a substitute to other inputs.

5. Conclusion

In most CGE models with special focus on farm policy, the on-farm wage either follows the ordinary wage in the economy or it is varies according to an assumption of sector specific farm labour. This paper demonstrates a practical and empirical consistent way to model farm household allocation of labour in CGE models, assuming that farm labour is *partially* sector specific. In this set up, preferences for farming and the relative wage between on-farm and off-farm work, determines the allocation of farm household labour between on-farm and off-farm work. Reallocation of labour as a response to change in relative wage, is assumed to be sluggish.

Using the Norwegian agricultural sector as a case, the paper demonstrates clearly that the farmers' preferences for on-farm work are of vital importance as to how a liberalisation of farm policy affects farm output and farmers' income. The results depend on technology; i.e. to what degree costs can be reduced by replacing hired labour, capital and other factors with cheaper family labour. Technology is especially important when preferences for on-farm work are high, i.e. when farmers accept to work at their own farm even if the wage falls substantially.

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