TAXATION AND FEMALE LABOUR SUPPLY IN JAMAICA: THE ECONOMETRICS OF NONLINEAR BUDGET CONSTRAINTS

by

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Taxation and Female Labour Supply in Jamaica:The Econometrics of Nonlinear Budget Constraints.

(Some very preliminary results-do not quote).

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Section I

In the light of the reform of many tax systems in developing countries in the 1980's the impact of taxation on work effort has gained considerable importance. In Jamaica, following the "supply side" [1]approach to tax reform, tax rates in general, and direct tax rates in particular have been reduced. This reduction in direct tax rates, however, was preceded by very little empirical evidence about the impact of taxes on labour supply and work effort. Thus the magnitude of the tax break required to generate a certain level of additional hours is unknown.

This lack of information may be due to the observation that large structural employment in many developing countries and the growing importance of the informal sector, make the impact on hours offered due to changes in marginal tax rates a matter of small importance (Gary Fields, 1987).

The impact is also assumed to be small because of institutional factors which may constrain the bulk of the tax paying population to vary its labour supply significantly. In Jamaica this

[1] .See Roy Bahl (1989), Alleyne (1999).

group would constitute most of the Pay-as-you-Earn (PAYE) taxpayers who contribute significantly to direct tax revenue. Another reason for the neglect of this issue in that in many developing countries, there has been the gradual movement away from direct to indirect taxes, with indirect taxes contributing the bulk of revenue and in some countries, direct taxes have been abandoned altogether.[2] In the Jamaican case however, direct taxes are an integral part of the tax system and the share of direct taxes to total revenue has varied between 36 and 40 percent between 1994/95 and 1997/98 respectively.

Rochjadi and Leuthold (1994,p.332)[3], in an econometric study of the relationship between taxes and labour supply for Indonesia, have also pointed out that due to the lack of suitable cross sectional labour market data in developing countries, the analysis of labour supply elasticities has been largely qualitative. Their study used ordinary least squares(OLS) to estimate labour supply elasticities by gender and area. The main problem with their approach, however, is that a linear budget constraint was employed when in fact progressive taxes generate piecewise linear budget constraints (Hausman, 1981).

The limitations of such an approach are well known. For example, Blomquist (1996) found that the use of ordinary least squares (OLS) to estimate a piecewise linear budget constraint biased the results severely. Rochjadi and Leuthold were aware of these shortcomings of their model and pointed out that preliminary attempts to use a more appropriate modeling strategy yielded results similar to that of OLS and such methods were not pursued. Most studies employing maximum likelihood methods tend to have higher elasticities than the OLS method (Hausman 1995, Pencavel 1986, MaCurdy et al. 1990).

Ribeiro and Leuthold (1999) in a recent study for Mexico also estimated labour supply functions utilising OLS and 2SLS techniques. They experimented with different functional forms in order to asses the sensitivity of the results to the functional form of the labour supply function chosen. Blomquist (1996) has also pointed to the limitations of 2SLS in estimating labour supply functions.

This study considers the impact of taxes on work effort for a sample of employed women in Jamaica, employing the Hausman (1981) method. This approach accounts for the complete form of the budget constraint and uses maximum likelihood methods to estimate the labour supply function. The model used also accounts for measurement error as well as heterogeneity of preferences. It is usually the case that measurement error tends to spread observations evenly over the budget constraint while heterogeneous errors tend to account for the clustering of observations around the kink point of the convex budget constraint (Graversen 1997, Blomquist (1997), Hausman1985). The model employs both a nonlinear and a linear specification, the former, to account for the possibility of having individuals on a backward bending labour supply curve.

The analysis uses the special Survey of Living Conditions (SLC) data set for 1993 which

[2] See Bain (1994) for reforms in the Eastern Caribbean and Zee (1996) for cross-country comparison of tax revenue from various sources.
[3] Se also Dillon Alleyne, "Taxation and Labour Supply : Evidence from Jamaica". Volume 1, Central Bank of Barbados, Working Papers, 1997.

included income from various sources, the hours worked and a number of socio-economic variables. Labour supply functions are estimated and elasticity estimated are computed. This paper is made up of six sections. Section II briefly outlines the Jamaican direct tax system, Section III outlines the model which informs the analysis, Section IV looks at the empirical specification of the model and section V reports the results. Section VI is the conclusion.

Section II: The Jamaican Direct Tax System

Before 1986, the Jamaican personal income tax system was characterised by a progressive tax structure with steep tax rates on relatively low levels of income.[4] The bill to amend the Income tax Act, introduced a proportional tax rate of 33 1/3 percent to be imposed on income above a threshold of J$8,580 per annum, but this was raised to J$18,408 in 1993. The threshold was intended to replace a large number of credits and allowances which were a major source of tax avoidance, (Bahl and Murray, 1996).

In 1993, the Revenue Board of the Government of Jamaica, surveyed a number of firms of various sizes to compute the overall effective income tax rates (Emoluments (PAYE) Survey, 1993).

[4] The Pre-reform tax system was characterised by a progressive tax structure in which the marginal rates rose from 30 % on the first J$7,000.0 of statutory income to $57.5 percent on income above J$14,000.00

Table I.A: Effective Tax Rates by Income Groups	
<$18,400.00	1..3%
$18,400-$24,,999.99	3..2%
$25,000-$49,999.99	7.0%
$50,000-$74,999.99	11.5%
$75,000-$99,999.99	13.1%
$100,000-$149,999.99	15.0%
$150,000-199,999.99	16.6
$200,000-$249,999.99	16.9%
$250,000-$499,999.99	18.6%
$500,000-$999,999.99	12.8%
$1,000,000 or more	14.9%

Table I.B Average Effective Tax Rates	
<$18,408	1..3%
$18,408-$74,999.99	7.23%
$75,000-$249,999.99	15.4%
>249,999.99	16.25 %

This was a reasonably representative sample since most of Jamaica's income taxes are paid by PAYE taxpayers, whose incomes are deducted at source, in both the public and private sectors. The self-employed contribute only a small proportion of income taxes.[5] Table I.A shows the results of the effective tax rates for the various income groups.

Given that there is little variation among the rates within broad income groups the average rates were computed for four income groups and used in the analysis (Table 1.B). Usually in studies of this kind the statutory tax rates are used to compute after tax income but in fact

[5] The contribution of the self-employed was 8.5 percent of the PAYE contribution in fiscal year 1994/95 and 5.6 % in 1997/98.

these may not be appropriate since they tend to overstate the effective rates. For this reason, the effective tax rates are employed in this study.

SECTION III: The Basic Model

A piecewise linear labour supply model is estimated for females based on the assumption that the data are generated by utility maximization with globally strictly convex preferences subject to the budget constraint. The budget constraint is typically written as,

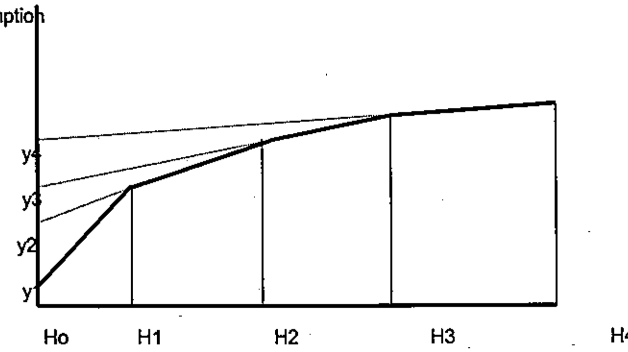
$$C = Y + Wh + I - T(A) \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where C is annual consumption, W is the hourly gross wage rate, h is the hours of work, Y is annual taxable non-labour income, I is annual non-taxable non-labour income, inclusive of spouse's after-tax income, and T is the tax amount determined by the tax function T(.). A is the annual assessed income; A = Wh + Y - D, where D is annual deduction in income.

In this analysis it is assumed that women take family income into account when deciding on labour supply decisions. For women then the unearned income variable I is equal to the sum of asset income and family earnings.

Given the effective tax rates in Table 1.B, the individual's budget set can be depicted as in Figure 1 below.

Figure I



The figure schematically represents the budget set of a typical individual in the 1993 Jamaican tax system. There are four wage segments and three internal kinks. The kinks are at the hours of work points, H_i, representing the maximum number of hours that an individual can work before her earnings advance her from tax bracket i to tax bracket i + 1 (i.e. from segment i to segment i + 1). The slope of each segment is given by the marginal wage rate for that segment, $w_i = (1 - t_i)W$, where t_i signifies the marginal tax rate for segment i.

The after tax non-labour income at zero hours (H_0) is y_1. Given that particular after tax non-labour income y_1, the 'virtual' income related to segment i can be obtained iteratively as

$$y_i = y_{i-1} + (w_{i-1} - w_i)H_{i-1}, \text{ for } i \geq 2 \cdots\cdots\cdots(2)$$
$$= y_{i-1} + (t_i - t_{i-1})WH_{i-1}$$

'Virtual' income is the intercept of the particular extended segment of the budget constraint on the vertical axis. The optimisation problem of the individual now becomes the following:

Max U(h,C)

s.t

$$C = \begin{cases} y_1 & \text{if } h = H_0 \\ w_j h + y_j & \text{if } h = H_{j-1} < h < H_j \quad j = 1,\ldots,k \cdots\cdots\cdots(3) \\ w_k H_k + y_k & \text{if } h = H_k \end{cases}$$

where k, the number of segments, equals 4 given the Jamaican tax system.

Hausman (1981), Burtless and Hausman(1978) and Blomquist (1983) outline the basic optimisation problem and the algorithm for the solution of the individual's optimisation problem. We outline the approach taken from Blomquist (1983) as follows:

> The budget line consists of the segments S_i, i = 1, 2, 3, 4. The marginal wage w_i and virtual income y_i correspond to each linear segment i. Denoting hours of work by h, the line segment S_i is valid for $h \in B_i = \{h \mid H_{i-1} < h < H_i\}$.
>
> The individual's preferences is given by a strictly convex utility function U(c, h). If this function is maximised subject to a linear budget constraint c = y + wh the labour supply function h = f(w, y) is determined. The 'desired' hours of work, h^*, can be computed for each extended segment of the budget constraint. Thus $h_i^* = f(w_i, y_i)$ where the extended segment is given by $c = y_i + w_i h$. If h_i^* lies in B_i then h_i^* is the unique global maximum. If $h_i^* \notin B_i$ then the optimum is elsewhere: on another segment, at a kink or at a corner. Blomquist (1983), p.172 states the algorithm as follows:
>
> "Compute $h_1^* = r(w_1, y_1)$. If $h_1^* < 0$ then we have a corner solution at zero, and $h^* = 0$. (We use h^* without subscript to denote the global optimum.) If $h_1^* \in B_1$, then $h^* = h_1^*$. If $h_1^* > H_1$, we go to segment z and compute h_2^*. If $h_2^* < H_1$, then we have a 'kink solution' and $h^* = H_1$. If $h_2^* \in B_2$, then $h^* = h_2^*$. If $h_2^* > H_2$, we go to segment 3, etc." Blomquist(1983),p.172.

Maximisation of a well-behaved utility function subject to the piecewise linear budget constraint yields the labour supply function: $h^* = r(w, y)$. As such the model is completely deterministic. However, besides the wage rate, the marginal tax rate and non-labour income there are other variables, not explicitly included on the model, which influence the supply of hours of work. A first step is to introduce a random error term, ε, to capture the effects of these omitted variables such that

$$h = h^* + \varepsilon \cdots\cdots\cdots(4)$$

By adopting an assumption on the probability density function (p.d.f.) of ε, the likelihood function, for the set of individuals for whom data on hours of work exist, can be obtained. Thus in principle, the problem of estimating the parameters of the labour supply function can be tackled.

Again, using Blomquist [1983] this likelihood function for the n individuals in the sample can be broadly stated as,

$$L = \prod_{ji=1}^{n} f(h^j \mid X,^j \theta) \cdots\cdots\cdots(5)$$

where the superscript j refers to the individual, X is the set of exogenous variables influencing hours of work and θ the set of parameters to be estimated.

Section IV: The Empirical Specification

The model assumes that the preferences of individuals between work and consumption are given by the following indirect utility function.

$$V(w,y)=\left\{y+\frac{\theta_1}{\theta_2}w-\frac{\theta_1}{\theta_2^2}+\frac{z\gamma}{\theta_2}+\frac{v}{\theta_2}\right\}e^{\theta_2 . w} \quad \ldots\ldots\ldots\ldots (6)$$

where w is the wage rate, y is non-labour income, z is a vector of personal or household characteristics and the parameters to be estimated are θ_1, θ_2 and γ. We follow the assumption in the literature that v is an error term which summarises the heterogeneity of preferences among persons with similar characteristics z . As Hausman (1985) has shown, the direct utility function associated with the indirect utility function above is given by

$$U(h,C)=\frac{1}{\theta_2}\left(h-\frac{\theta_1}{\theta_2}\right)\exp\left[\frac{\theta_2 C-h+z\gamma+v}{h-\theta_1/\theta_2}\right] \quad \ldots\ldots\ldots\ldots (7)$$

where C is consumption and h is the observed number of hours worked.

An individual who is working and is faced with a linear budget constraint, with slope w and intercept y, has desired hours of work defined by the following linear function which is consistent with (6) and (7) above; $h = f(w_i, y_i) = x_i\,\theta + v \qquad i = 1, \ldots, 4$ ....(8) where v is an error component representing heterogeneity of preferences among individuals with $v : N(\mu_v, \sigma_v^2)$, in other words v captures variations in utility function across individuals. x_i is a set of explanatory variables which include the wage rate and income variables plus variables reflecting other observable characteristics presumed to affect labour supply. In addition to the error component v it is further specified that there is an error component ε reflecting errors of measurement so that measured labour supply $\hat{h}=h+\varepsilon$ i.e. measured labour supply is equal to actual labour supply plus an error component. It is assumed that $\varepsilon : N(0, \sigma_\varepsilon^2)$ and $E(v\varepsilon) = 0$. The double error specification is due to Burtless and Hausman(1978) and is discussed in Moffitt (1986). The rationale for the introduction of measurement error lies in the fact that while the maximization problem of the basic model will tend to cause a bunching of individuals at kink points, the empirical observations normally do not show bunching of individuals at the kink points or even in the neighborhood of kink points (Graversen and Smith ,1998, Moffitt, 1986).

In the first specification the after tax wage w_i and virtual income y_i are added linearly as follows:

$$h=\theta_1 w_i + \theta_2 y_i \quad \ldots\ldots\ldots\ldots (9)$$

Labour supply (9) which is consistent with utility maximisation in equation (7),

satisfies the condition, $$\frac{\partial h}{\partial w}\Big|_{\bar{u}} = \partial h / \partial w - h\left(\frac{\partial h}{\partial y}\right) > 0$$

Since $\partial h/\partial w = \theta_1$ and $\partial h/\partial y = \theta_2$ then $\theta_1 - h\theta_2 > 0$ (see Blomquist,1983, p.178).

We also employ a specification wherein the terms involving w and y are added nonlinearly as follows:

$$h = \theta_1 \ln w_i + \theta_2 (y_i / w_i) \quad \text{.....................................(10)}$$

As Graversen (1997, p.5),points out, this specification allows for a backward bending labour supply for some or all individuals if $\theta_1 < 0$ and $\theta_2 < 0$.

It should be noted that h^* is not enough to allocate individuals to their respective budget segments nor to identify their marginal tax rates, except when hours of work are zero (Graversen 1998). This can only be gleaned for the actual hours of work, h. The result is a discrete –data version of the errors –in-variable problem, thus the stochastic specification then is as follows:

$$h = \begin{cases} H_0 + \varepsilon & \text{if } h_1 + v \le H_0 \quad \text{lower limit} \\ \hat{h}_j + v + \varepsilon & \text{if } H_{j-1} < \hat{h}_j + v \le H_j \quad \text{segment } j, j = 1,...,k \\ H_j + \varepsilon & \text{if } \hat{h}_{j+1} + v < H_j < \hat{h}_j + v \quad \text{Kink } j, j = 1,..,k-1 \\ H_k + \varepsilon & \text{if } \hat{h}_k + v > H_k \quad \text{upper limit} \end{cases} \quad \text{..................(11)}$$

The results in (11) combine the discrete and continuous parts of the choice to create an estimable model. and the likelihood function is as follows:

$$L = \prod_{i=I} G(h_i^* = 0) \prod_{i=J} g(h_i^*) \prod_{i=K} g(h_i^* = H_k) \quad \text{..................(12)}$$

where G(.) is the cumulative density function, and g(.) is the derivative $\delta G(.)/\delta x$. The expressions for the densities are given in Arufat and Zabalza (1986), Moffitt(1986). Note that I is the number of persons who are not in the labour force that is $(h^* = 0)$, J is the inedx for persons who are participants and who have not reached the maximum number of labour hours, and K measures the number of persons with h_k hours of work or greater. The expressions for the density for participants is given in appendix I,

Section V: Data and Preliminary Empirical Results

The data set employed in this analysis was the SLC 1993 data set which collected income data on individuals in he sample. There were 963 female labour market participants in the sample,of which , 893 had a positive value for total hours and wages. The descriptive statistics of the variables are given in Appendix II.

The variable in the linear specification are age of individuals (AGE), AGESQ to capture the quadratic effect of increasing age on hours offered, years of primary(YPM) and years of secondary education (YSC) which capture the fact that education tends to increase labour market participation. A dummy variable of 1 computed for Kingston, with zero representing other towns and rural areas. The variables CHILD6 and CHILD18 represent the number of children 0-6 years and the number of children between 7-18 years respectively, designed to capture the impact of children on the hours offered by women. The variable (WG) is the after tax hourly wage which is computed as annual after tax wage divided by number of annual hours. There was no property income so virtual income (Y) was computed as average household remittances plus family income.

Table II reports the maximum likelihood and the OLS estimates for the linear specification only and the results are for participants.

Maximum Likelihood estimates			OLS Estimates	
Variables 't'vales		Parameters	Parameters 't'values	
Constant 10.510		0 .1749	0.1786	8.88
YPM/100 0.085		0.0373	-0.1163	-1.13
YSC/100 0.028		0.0025	0.0531	0.50
AGESQ/10000 3.643	-0.3171	-	-0.3027	-2.86
AGE /100 2.861		0.2205	0.2335	2.49
KINGSTON	0.0094	2.336	0.0074	1.56
CHILD6 1.403		0.3481	0.0027	0.92
CHILD18	-0.3145	-2.317	-0.0038	-2.35
WG/1000 7.550		0.2703	-0.0003	-4.81
Y/1000000 0.774	-0.0669	-	0.0379	2.93
SIGMA-ε 1.749		0.0558	-	
SIGMA-v 0.019		0.0058	-	
No of Obs	893		893	
Mean log lik(1.43083)		SE**	-	SE**
*ε-uncompensated wage 0.056		0.035	-0.000	0.000
ε-Income 0.031		-0.024	0.0137	0.180
ε-compensated wage 0.058		0.037	0.0009	0.001
*ε-elasticity				
**Standard error				

The average elasticity was computed on the assumption that the individual lived in Kingston and had one child six years old or less and one between seven and eighteen years.

The maximum likelihood (ML) estimates are theoretically consistent in sign for the income and wage variables. The education variables are insignificant in explaining hours offered but the age variables, the variable for number of children between 7-18 and the net hourly wages are significant. The dummy for Kingston is also highly significant at the 95% level. The income variable while negative is insignificant.

In the case of OLS estimates, the sign on the income variable is inconsistent with theory as it is positive while the wage variable is negative. This is not unusual as Leuthold and Ribeiro(1999,Tale 1) found similar results. The results also show that while (SIGMA-v), which accounts for heterogeneity of preferences is small, and insignificant, (SIGMA-e), which accounts for optimising errors, is significant. Because the analysis is done only for female participants, they should be interpreted with caution. Graversen found that when all workers, participants and non-participants, are accounted for, the variance of the two error terms, the age variables and the average elasticities are reduced.(Graversen,1997, pp.14-15).

Appendix III sets out the elasticity estimates for the linear and non-linear specifications, but at this stage only the estimates for the linear specification are reported. For the ML estimates, the signs are as expected with an average income elasticity of –0.024, an uncompensated income elasticity of 0.035 and a compensated wage elasticity of 0.037. These results are much lower than those for developed countries. For example Graversen (1996) found average compensated elasticities for men in Denmark in the range 0.13 and 0.23, and average income elasticities for women as –0.15. Their average compensated wage elasticity was 0.68

Our results are of similar orders of magnitude to results found by Leuthold and Ribeiro (1999), except that they found negative or backward bending labour supply effects. For example, using 2SLS and a set of instruments their wage elasticity was –0.051 and income elasticity of –0.011, with compensated wage elasticity of 0.098.

Our OLS results show much lower elasticities and may even be inconsistent since non-linearities are not accounted for in the estimation. The compensated wage elasticity was –0.0009 and the income elasticity was positive with a value of 0.01372. The uncompensated income elasticity was negative and thus inconsistent with the underlying theory.

Section VI: Conclusion

Our results suggest that the OLS estimates are inconsistent and probably very misleading. Models that employ techniques accounting for heterogeneity of preferences and the non-linearity in budget constraints are more appropriate. The preliminary results for maximum likelihood estimates suggest that the elasticity estimates though relatively small are not trivial and may help to better inform the magnitude of tax reductions contemplated by public policy makers.

Appendix I

With respect to the likelihood function equation (12), the density functions for $g(h_i^*)$ is shown below where $b_1(.)$ and $b_2(.)$ are bivariate densities of (ε, v) and $(\varepsilon + v, v)$ with means and variances $(0,0,\sigma_\varepsilon^2+\sigma_v^2,0)$ and $(0,0,\sigma_\varepsilon^2+\sigma_v^2,\sigma_v^2,\sigma_v^2)$. See MaCurdy and Blundell , p.1632; Graversen, 1996, p.7.

It is usual to assume no correlation between e and v. The term $g(\dot{h}_i)$ expresses the probability of observing persons on each of the four segments. Following Graversen, 1997 ,Blundell and MaCurdy 1999, the limits of integration are given as

$\bar{z}_{ji} = H_{(j+1)i} - h_{ji}$ *and* $\tilde{\tilde{z}}_{ji} = H_{ji} - \hat{h}_{ji}$, and the likelihood function for participants is given as follows:

$$
\begin{aligned}
g(h_i^*) = & \int_{-\infty}^{\tilde{z}_{ji}} b_1[h_i^* - H_0, v_i]dv_i \quad \text{lower limit} \\
& + \sum_{j=1}^{4} \int_{\tilde{z}_{ji}}^{\tilde{\tilde{z}}_{ji}} b_2[h_i^* - \hat{h}_{ji}, v]dv_i \quad \text{Segment } j, j = 1, \ldots, 4 \\
& + \sum_{j=1}^{3} \int_{\tilde{\tilde{z}}_{ji}}^{\tilde{z}_{(j+1)i}} b_1[h_i^* - H_{ji}, v_i]dv_i \quad \text{Kink } j, j = 1,2,3. \\
& + \int_{z_{4i}}^{\infty} b_1[h_i^* - H_4, v_i]dv_i \quad \text{Upper limit}
\end{aligned}
$$

Appendix II

Appendix II Means and Standard deviations of the variables used in the analysis.			
Variables	N	Means	Std Dev
Hours	893	2050.195	682.951
Ypm	893	5.528	2.2813
YSC	893	2.380	2.5456
Age	893	37.013	13.5382
Kingston	893	0.374	0.4841
Child6	893	0.7390	1.08402
Child18	893	2.1444	1.97187
Gwage*	893	23.0247	29.61520
Y	893	0.1216	0.18620
Tax rates	893	0.07073	0.0455833

*Gross hourly wage.

Appendix III

The elasticity estimates for the linear specification are as follows:

$$\varepsilon_{ucw} = \frac{\delta h}{\delta w}\frac{w}{h} = \Phi\left(\frac{x\theta}{\sqrt{\sigma_\varepsilon^2 + \sigma_v^2}}\right) * \theta_1 * \frac{w}{h}$$

$$\varepsilon_y = \frac{\delta h}{\delta y}\frac{y}{h} = \Phi\left(\frac{x\theta}{\sqrt{\sigma_\varepsilon^2 + \sigma_v^2}}\right) * \theta_2 * \frac{y}{h}$$

$$\varepsilon_{cw} = \frac{\delta h}{\delta w}\frac{w}{h}\Big|_s = \varepsilon_{cuw} - \frac{w * h}{y} * \varepsilon_y$$

The elasticities for the non-linear specification following Duncan[1990], Graversen[1998] is as follows:

$$\varepsilon_{ucw} = \frac{\delta h}{\delta w}\frac{w}{h} = \Phi\left(\frac{x\theta}{\sqrt{\sigma_\varepsilon^2 + \sigma_v^2}}\right) * \left(\theta_1 - \theta_2 * \frac{y}{w}\right) * \frac{1}{h}$$

$$\varepsilon_y = \frac{\delta h}{\delta y}\frac{y}{h} = \Phi\left(\frac{x\theta}{\sqrt{\sigma_\varepsilon^2 + \sigma_v^2}}\right) * \theta_2 * \frac{y}{w * h}$$

$$\varepsilon_{cw} = \frac{\delta h}{\delta w}\frac{w}{h}\Big|_s = \varepsilon_{cuw} - \frac{w * h}{y} * \varepsilon_y$$

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