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FACTOR ENDOWMENTS, BIASED TECHNOLOGICAL CHANGE, WAGES AND POVERTY REDUCTION: CAN GENETICALLY MODIFIED CROPS BRING A GREEN REVOLUTION TO SSA?

BACKGROUND

1) The basic question addressed by the project is can a labour-saving GM technology, such as herbicide-tolerant (HT) white maize, provide agricultural growth in SSA, or is the most probable outcome simply increased under-employment in rural areas? The project has three clear parts.

1) The first is the fieldwork-based data collection in KwaZulu Natal (KZN), which aims to measure the output and employment effects of the new technologies. This is analysed to determine the impact of the new technologies and is essential to the success of the project.

2) The second stage is to use the data from the KZN surveys to calibrate a household model of Malawi, as we need to determine the impacts in a simulation model and this one is for a more typical country in SSA. It shows the expected impacts on output, employment and incomes that cannot be inferred from the survey alone.

3) The other (preliminary) task is the desk-based background research needed to put the field results in context. This uses secondary data sources, such as the FAO and the World Bank, to measure the growth and biases of agricultural productivity for a wide range of developing countries. This is to determine if the relatively land-abundant countries of Africa failed to benefit from the green revolution because it was inherently land saving and labour using. This was to help determine which areas will benefit from labour saving GM technologies.

Shortcomings in Current Knowledge

Despite substantial work on the (lack) of a green revolution (GR) in SSA, there has been little work on factor endowments and biases since Hayami and Ruttan (1985). There are no empirical papers on the effects of these biases on wages and labour incomes, or on poverty reduction. For instance, Thirtle *et al* (2003) considered only yields and had no wage data.

Objectives (and Research Questions)

We stated objectives very succinctly, as we also listed shortcomings in existing knowledge and research questions.

The objectives were to:

1) predict the impact of GM on output growth, employment, wages, food prices and livelihoods, according to factor endowments and agro-climatic zones
2) assess the overall impacts on labour incomes and finally on poverty reduction
3) inform the policy process by providing national and provincial agriculture departments and national agricultural research services with the options available and likely outcomes of GM adoption

We think 1) has been answered, but for SSA and Africa relative to Asia, as trying to separate climatic zones was not enlightening. 2) was answered in some detail. We collected information on days of family labour by task by gender and by age group and days and costs of hired labour by task. Simulations of the impact of GM in Malawi are reported below. This modelling allows us to estimate the net output, income and employment effects, which cannot be done directly from the survey.

The third objective was clearly met and the details are given in the final sections of this report. We are particularly pleased that the biotechnology regulatory authority requested a special report on our findings (Gouse et al., 2008). There are also presentations at conferences, published papers and reports and we have directed a wide range of interested parties to the website. See details below.

The objectives relating to the **background study** were stated in more detail as research questions, answered in Piesse and Thirtle (2008), which is published in a special issue of a journal on agricultural biotechnology.

1. How different were the rates of agricultural productivity growth in Africa, Asia and Latin America and how different were the factor saving biases?

2. Do factor proportions play a major role in explaining the **rate and biases** of technological change, across space and time, during the GR era? Do the biases of the GR technologies fit the factor proportions in Asia and Latin America better than in SSA? Are these differences between Asia and Africa important in accounting for Asian success and comparative failure in Africa, or do markets, institutions and infrastructure dominate?

3. Do the biases of the GR technology really explain its impact on wages and non-wage labour incomes in Asia and SSA? How much do lower food output prices account for rises in real wages and poverty reduction?

4. What is the poverty reduction elasticity of GR-driven agricultural output growth across time and space? Is it the same in SSA and Asia?

5. Do the partial productivities of land and labour have different poverty impacts, especially in SSA?

We think the paper addresses all of these concerns. We discuss our answers further in the **Results** section that follows. The other objective, discussed in Section 4 of the proposal, was to test this proposition raised by Lipton.

Linking productivity, biases and labour remuneration

Lipton (2005) stresses the importance of factor saving biases. In comparing GM with the GR technologies, he argues that GR was pro-poor because it increased yields (output per unit of land - Q/A) more than labour productivity (output per unit of labour - Q/L). Lipton claims that as the rural labour supply in LDCs is still expected to increase at over 1% per annum, despite HIV/AIDS, Q/A must increase at least 1.5% per annum faster than Q/L for employment and wages to increase and reduce poverty. In proportional terms, with the changes expressed as time derivatives, this is

Demand for Agricultural Labour **Supply of Agricultural Labour**

$$\frac{d\ln Wa}{dt} > 0 \ iff \ \frac{d[\ln(Q/A)]}{dt} - \frac{d[\ln(Q/L)]}{dt} > \frac{d[\ln La]}{dt} = \frac{d[\ln Lt]}{dt} - \frac{d[\ln Lna]}{dt} \quad \textbf{(1)}$$

where W_a is the agricultural wage, or the return to labour, d[lnLa]/dt is the proportional growth over time of the agricultural labour force, d[lnLt]/dt is growth in the total labour force and d[lnLna]/dt is growth in the non-agricultural labour force. This proposition is investigated in Piesse and Thirtle (2008), especially in Section 7. The paper shows that this proposition has many aspects to it, which are discussed there and in the **results** section below.

The **survey and the household model** also relate to all the objectives and are discussed in Section 7 of the proposal. The objectives relating specifically to these parts of the study were again stated as research question, but the publication on the 2006/07 data (Gouse et al., 2009) does not explicitly answer them. The main aims that have been addressed can be summarised as the need to measure:
1) the output and employment effects of the GM varieties
2) the labour use by task and type, to determine the employment impact more explicitly
3) the impact on household incomes (but the details listed proved to be hard to determine)
4) the impact on households that are resource poor and depend substantially on wage labour.

METHODS

For the **background materials** from secondary sources, the possible models are listed and discussed in section 6.3 of the original proposal and in the Annex, sections 1 to 3. The plan was to start at the highest level of generality and work downwards to isolate the more interesting results. So, we started with a sample that included all the 150 countries for which the FAO has data, reduced somewhat by missing variables, and estimated production functions. The full sample is intractable mostly because there are too many regions, which leads to messy results. The results that can be found in the next section are mostly published in Piesse and Thirtle (2008), which relate very directly to what this section said it would produce. For model 1 of the Annex, we reduced the sample to Africa and Asia as this was the most important and meaningful comparison, with clear publishable results, on factor saving biases and productivity growth. The basic approach that gave the best results was a random coefficients model of yields and labour productivity. The bias results show that it is Africa and Asia that should be included, as too many Latin American countries are past the turning point in the structural transformation. For modelling the impact of R&D on productivity, the Annex model 2 sample is 21 rather than 23, due to missing data. The ECM does not give acceptable results, so we stop with a translog stochastic frontier, random effects panel model. The alternative to this, which we report below, follows the pattern of trying to account for land and labour saving productivity growth. To do this we estimate simultaneously Cobb Douglas yield and labour productivity equations using three stage least squares and seemingly unrelated regression. For Annex model 3, which considers explaining wages, prices, GDP and $1 per day poverty reduction, we need as large a sample as possible as the constraint is the limited number of poverty surveys, so we use Africa, Asia and Latin America. So far, we have results published from single equation estimates, rather than simultaneous systems, so we explain what else may be done in the appropriate section of the report. None of the econometric methods is inherently novel, but no novelty was promised. It is much more a matter of matching the available data with the most suitable technique to produce robust results.

For the **surveys,** we do not detail the data collection methodology as it was not exceptional in any way, except that the enumerators have now been with us for several years and are increasingly proficient. The proposed sampling method, sample size, structure, content and locations are discussed in A.4 of the Annex. The crucial point of the surveys is to isolate the impacts of the different elements of technology and land preparation techniques.

However, a major contribution was in the in-depth coverage of the survey. We now have a sample of nearly 600 observations over two years, with 190 farms common to both years. Each farm was visited 7 times per year to capture the labour use by task throughout the season. In addition, the labour is disaggregated into family or hired and men, women and children.

The analysis of the survey is unexceptional, apart from the fact that two years of data constitutes a panel and allows us to separate the effects of the technologies from farm and farmer specific characteristics, as we explain in the results section.[1] Again, this is not so much a matter of path breaking new techniques, as of matching the data and the methods. We analyse the data statistically, looking at yield and labour productivity impacts of Bt, HT and stacked gene (SG) varieties, relative to the best conventional seed (Panaar) and all other conventional varieties. Then we look at gross margins to compare the profitability of the varieties and finally we fit translog stochastic production frontiers to compare the efficiencies of the varieties with respect to all the inputs. The results for the first year are in Gouse et al. 2009) and those for the second year in Gouse et al. (forthcoming).

With the second season data not completed until December 2008, we have yet tried to add the analysis of risk to the analysis and as Section 7.1 of the proposal said, Bt is a risk avoidance strategy and should be modelled (see Shankar, 2007, for example). Nor have we yet undertaken the more methodologically advanced items in 7.3 of the proposal.

The **modelling** work used farm household programming models of Malawi, as described in Dorward (2006). A major feature of the livelihood model is consideration of labour use and supply, consumption, cash flows, prices, wages and cropping activities in four separate periods – cropping (November to January), pre-harvest (February to March), harvest (April to June) and post-harvest (July to October). This captures the impact of seasonal cash flow constraints and the 'hunger gap' for poorer households in the cropping and pre-harvest periods. The model also allows for risk aversion leading to a preference for maize cultivation by including net income achieved under two states of nature in the objective function, with post harvest maize consumption and maize stocks valued at 'expected' and 'high' maize prices.

Cluster analysis of data (not part of this project) was used to develop a household/livelihood classification within the major livelihood zones of the country. Two sets of livelihood models have been developed for the two largest agro-ecological zones in the country (in terms of population): the Kasungu Lilongwe Plain and the Shire Highlands. These two zones include just over 40% of rural households in Malawi and represent examples of less and more densely populated areas in the centre and south of the country. Modelling of maize and labour market interactions between different households in a zone is achieved by aggregating model outputs across different household types (or clusters) in a zone, taking account of the number of each type of household, then adjusting wages and maize prices in an iterative manner.

The baseline scenario for the current work (without HT maize) is essentially the outcome of previous work. The model investigates firstly the circumstances under which Malawian

[1] We originally used this approach in our work on Bt cotton in Makathini Flats (Thirtle et al., 2003)

households in the zones above and with different characteristics might adopt HT maize, and secondly the impacts of such adoption on food production, labour market outcomes and poverty.

The first challenge was to describe what a HT maize technology might look like within a Malawi context. Using our South African data we devised a technology that, in relation to existing local hybrid varieties (on which it would presumably be based):

- Carried a 40% higher seed cost;
- Saved all weeding labour (roughly 30% of all labour input), with only a very modest requirement for labour used for herbicide application;

This achieved a 10% higher yield, based on more effective weed control through herbicide application. The basis for these assumptions was simple regressions using the KZN data. In the absence of specific data for Malawi, herbicide was priced at the South African-equivalent price of US$8.4 per litre.

As the technology premium (the difference in price between conventional and HT seed) is a marketing decision for the seed company, the modelling also considered the consequences for technology adoption and outcomes of a lower (10%) price premium, as well as of a higher (30%) yield premium from HT maize. All scenarios were run with and without access to credit for seed and herbicide (not fertiliser) to simulate the impact of a promotional campaign by the seed company to encourage uptake of HT maize in Malawi.

RESULTS

Summary The main outcome of this project is not what we expected, as we began with an idea that Bt varieties were suitable for a semi-subsistence environment, such as these farmers in KwaZulu Natal, but that HT varieties were likely to displace labour. After all, they were all developed in the US with the express intention of eliminating weeding costs. This proved to be more variable, due to the flexibility with which HT has been applied in KZN. The HT varieties are only marginally labour saving and instead are being used in conjunction with minimum tillage to reduce soil erosion. Sustainability is repeated stressed as an objective and now we find HT is saving soil erosion while Bt is reducing the level of toxic chemicals, so both can contribute to the green agenda. If Bt, HT and stacked gene (SG) (ie both traits) maize reduce environmental degradation, increase yields and do not displace labour, it is hard to argue they cause damage.

Background results We have assembled two datasets. One covers Africa and Asia, so it does facilitate comparisons that aim towards discovering if the green revolution technology naturally favoured Asia, due to its resource endowments. For these countries we now have estimates of the rate of productivity growth and its factor-saving biases. We have attempted to use factor ratios as an explanatory variable to explain both rate and bias and have included the agricultural wage in the analysis. These results are given in Piesse and Thirtle (2008), which includes results from agricultural wage data from the ILO that were collected for this project.

One key discovery using the FAO data from 1961-2006 is that Africa has almost matched Asia in terms of yield growth, when yield is measured by value added per hectare. The Asian average of 2.6% is well above the average for Africa, which is 2.0%, but this is far higher than most would expect, given that African agriculture is regarded as failing. Over half the African sample (22 of the 42 countries) had yield growth of over 2% and only eight had less than 1%. However, the huge difference is that this yield growth translated into labour productivity growing at an average of 1.5% per annum in Asia, where only five of the twelve countries had less than 1% growth. For Africa, labour productivity grew at only 0.4% per annum and although the top few countries are in the same league as Asia, almost half the sample (18 countries) actually have negative growth in labour productivity. This has serious connotations for poverty reduction, as the paper shows that there is a strong correlation between labour productivity growth and poverty alleviation. We think this is to be expected, as incomes must be related to labour productivity.

Where does this leave Lipton's (2005) condition for poverty reduction stated in equation 1) above? We suspect that the secret is that for land scarce Asia, labour demand was rising, but supply was increasing less fast. Asia's growth in labour productivity is the result of several Asian countries passing the turning point in the structural transformation. Once labour is being withdrawn from agriculture, its productivity rises. Our results say that the land saving bias of productivity growth in Africa means it will be more pro-poor than Asia, on the demand side. However, for Africa, where almost no countries have reached the turning point stage, the population growth part of Lipton's inequality is the key. The crude FAO statistics show labour productivity falling because the rural population is still rising and thus the supply effect dominates. This proposition needs to be investigated more carefully.

The fact that extensification seems to have mattered more than yield increases, at least in countries like South Africa, with a relatively abundant supply of marginal land, suggests that labour-saving technology may be appropriate and/or better for some countries or regions than others. If this is true, then the poverty impact of the stacked gene (SG) technology, which we expect to become dominant, will be in the right direction. However, we have an odd outcome, in that the labour saving bias that was expected from the HT technology has been reduced by its use in minimum tillage systems.

The more detailed data for the 22 African countries that are central to the project has also been assembled. This covers just the countries for which we have long time series on annual agricultural R&D data and can try to explain the rates of productivity growth. This analysis has reached a reasonable degree of refinement, as we said above. The simultaneous model explains 82% of the variance in yield, with the R&D elasticity at 4.1% per annum and 61% of the variance in labour productivity, with R&D contributing 4.2%. Clearly, these models need to be further developed and will lead to publications.[2]

The background analysis triggered by investigating the inequality of equation 1) has led to a series of simple OLS regressions that are reported in Piesse and Thirtle (2008). We first showed that labour productivity is the key variable in explaining agricultural wages. For Africa, it has an elasticity of 0.85 and is significant at the highest levels, whereas yields have little impact or significance. So, Africa's lack of labour productivity growth is very directly reflected in wages. The land labour ratio is significant and negative, meaning that the more land abundant countries have lower wages. So, if wages are important to explaining poverty the semi arid countries of south and east Africa may be disadvantaged. For both Asia and Latin America, the effect of labour productivity is weaker, but yields are important and the land labour ratio has the opposite sign. It is the countries with lower population pressure that have higher wages. The next step was to establish that agricultural wages and partial productivities

[2] Note that we eschew TFP estimation. This is in part because it disguises the biases, which are central to our investigation. However, it is also because one of us has reviewed a paper that estimates a sequential Malmquist index for these same data. As this is exactly what we would have done (following Suhariyanto and Thirtle, 2001), this option is no longer available. We have been beaten to it.

explain GDP per capita. Then, poverty reduction is explained by wages and labour productivity. Greater rural population density is poverty reducing in Africa, which again suggests that the semi arid countries with abundant marginal land may have a problem.

It is not really possible to test Lipton's proposition of equation (1) because it requires growth rates, which are hard to calculate with these incomplete series. However, Piesse and Thirtle (2008) show that labour productivity seems to dominate yields in explaining poverty reduction and more land per labourer does not reduce poverty. In fact, the countries with more population pressure seem to do better, so again there is cause to consider how the land abundant countries of SSA should proceed.

Survey results[3]

Table 1 shows the number of farms surveyed.

Table 1: Number of farms, by district and seed type

2006/07	Conventional	Bt	HT	Stacked	Total
Simdlangentsha	59	3	7	0	69
Dumbe	76	9	0	0	85
Hlabisa	39	21	35	0	95
Total	174	33	42	0	249
2007/08					
Simdlangentsha	45	29	45	9	128
Dumbe	66	22	15	1	104
Hlabisa	32	11	38	20	101
Total	143	62	98	30	333
Grand total	317	95	140	30	582

The problems we faced are explained in Section 2 of the report. The 2007/08 data have been used to estimate a Cobb Douglas stochastic frontier and the efficiencies by seed type are reported in Table 2. The results are unusually straightforward as for the full sample and for each district separately, the stacked gene variety has the highest average efficiency levels by some clear margin. It is followed by the HT variety, which is always a clear second, with average efficiencies that are almost 9% lower. The Bt variety is on average the third most efficient, but the margin of improvement over the conventional varieties is only 1.6% and in Hlabisa, Bt is actually somewhat less efficient than the conventional varieties. This confirms the results of our previous studies, which all showed that the Bt seed does not pay for itself in a dry year, when stalk borers are not a problem. In this relatively wet year, the extra yield is just enough to cover the cost of the more expensive seed, but the difference is hardly sufficient to generate much enthusiasm. It seems likely that the HT will continue to spread, but the stacked gene variety more than pays for itself.

[3] The results of estimations using the 2006/07 data are available in Gouse et al. (2009), which is available on our website. We concentrate here on the 2007/8 season as these are not yet available in published material.

Table 2: Efficiency Estimates from the Stochastic Frontier Model 2007-8 (Rank)

District and Seed Variety	**Efficiencies by District and Seed Type**			
	Bt	Herbicide T	Conventional	Stacked
All Farms	0.5777 (3)	0.6475 (2)	0.5614 (4)	0.7098 (1)
Hlabisa	0.6609 (4)	0.7251 (2)	0.7074 (3)	0.7492 (1)
Simdlangentsha	0.5786 (3)	0.5976 (2)	0.5456 (4)	0.6262 (1)
Dumbe	0.5135 (3)	0.6041 (2)	0.5123 (4)	0.7152 (1)

The next question is the possibility of selection bias, as it may be the best farmers with the best resources that have switched technologies. This was the approach we took in Thirtle et al. (2003), which seemed successful at the time. We now have fairly convincing evidence of a second, countervailing self selection process. In most cases those who changed from a conventional seed variety to GM had done significantly worse than those who stayed with the conventional seed. It would make perfect sense that the "best farmer" self selection process may be less powerful than the "this technology is not working for me" self selection process.

We illustrate this with just one example from the two years of data. We compare the farmers who switched from Panaar to Bt, with those who stayed with Panaar. Those who stayed had 31% higher yields than those who changed, when both were using the conventional technology. As it happened, it was a year in which stalk borers were a problem and those who changed did very well indeed, getting yields 102% higher (ie more than double) than those who stayed with Panaar. So what is the technology effect? Had we found that those who moved were superior with the same technology, we would have attributed only the gain over and above the initial difference to the technology, calling the rest farmer attributes. In this case, that argument would mean that the 102% would have to be increased by 31% as these farmers had negative attributes. We think this is not the case. As explained there is a failed technology effect that is more important than any unmeasured attributes.

This would mean that the approach we used in 2003 was fundamentally flawed, but so are all the self selection models that first model adoption as a function of attributes and then estimate efficiencies. The second self selection process needs modelling too and this morass may take some time to unravel. We say it is dominant as in almost all cases it is those who are doing less well with a technology that change. With three GM and several non-GM choices it makes sense to shop around and these farmers certainly do. Whereas in the 1999 and 2000 studies of Bt cotton in Makathtini Flats, no Bt adopters moved back to conventional seed, in these surveys the two years show that all possible changes occurred. Some farmers even moved back to varieties that seemed never to have done well, so here the problem is to go back and find out if the move was forced by lack of alternatives or some other reason. The level of complexity regarding technology choice changes is clear in Table 3, which has those who did NOT change on the principal diagonal, so the off diagonal elements are all the changers. The last row shows that 22 farmers shifted to the new stacked gene variety in the second season.

Table 3: Productivity Growth Rates 2006-7 & 2007-8 (%) Panel of same 190 plots

Productivity measures	2007 - changed to:	2006 - changed from:			
		Bt	Herbicide T	Pannar	Other
Number of farms	Bt	**8**	5	6	15
Number of farms	Herbicide T	4	**27**	6	22
Number of farms	Pannar	2	6	**29**	13
Number of farms	Other hybrids	3	2	5	**17**
Number of farms	Stacked gene	8	8	2	4

The other main concern was the effect of the HT varieties on employment, as it was developed as a labour saving technology. Gouse et al. (2009) shows that Bt actually saves more labour than HT. Indeed, Bt seems to be twice as labour saving, reducing the input by 28% relative to conventional seed, whereas HT causes only a 13.7% cutback. The labour data for the second season gives different results and when it is fully analysed we expect it to show that there is no real difference between Bt and HT. There is also no tendency for hired labour to be dismissed (positive) but equally well no marked reduction in child labour, which we would have regarded as a plus.

Household Model Results

The results are for the Kasungu zone, an area of above-average sized farms, accounting for perhaps 40% of national maize production. This area will later be contrasted with the poorer, more densely populated Shire Highlands.

Adoption of HT Maize

Table 4 shows the seven stylised household types within the Kasungu zone and the extent to which each adopts HT maize under different scenarios[4]. We believe that scenario 1 is the most plausible in the Malawi context[5].

Table 4: Results from the Household Model for Malawi

					Area Planted to HT Maize (ha) under scenario:						
HH Type	Share in Rural Population	Land Area (ha)	Baseline Income (MK)	Baseline Non-farm (%)	0 Base	1 HT no credit	2 HT credit	3 10% tech premium no credit	4 10% tech premium credit	5 30% yield premium no credit	6 30% yield premium credit
1	0.29	1.33	61169	48%	0.0	0.20	0.25	0.23	0.25	0.21	0.21
2	0.21	0.93	49176	63%	0.0	0.00	0.23	0.00	0.25	0.00	0.28
3	0.12	0.78	36531	53%	0.0	0.01	0.14	0.02	0.14	0.04	0.12
4	0.09	0.79	39681	61%	0.0	0.00	0.00	0.00	0.18	0.00	0.23
5	0.08	2.05	79476	28%	0.0	0.22	0.22	0.28	0.22	0.55	0.55
6	0.09	0.95	85361	69%	0.0	0.24	0.20	0.25	0.20	0.21	0.18
7	0.12	1.75	66863	22%	0.0	0.18	0.18	0.18	0.18	0.38	0.38

Notes: nominal exchange rate, US$1 = MK105 (December 2003); 2005 PPP exchange rate, US$1 = MK39.46 (http://go.worldbank.org/UI22NH9ME0)

[4] Note that these are first-round results, i.e. before iterative changes in seasonal wage rates and maize prices are taken into effect. As is often the case, wider economy effects will tend to reduce adoption somewhat.
[5] The four less-poor households might be offered credit, but comparison of scenarios 2 and 3 suggests that this makes little difference to their adoption decisions.

According to these results, the four less-poor household types (#1,5-7) adopt HT maize even without access to credit. For these households, HT maize replaces conventional hybrid varieties, suggesting that an HT maize variety could quickly establish a significant share of the market for improved maize seed in Malawi. Interestingly, access to dedicated credit makes little difference to the adoption decisions of these households, suggesting that the modelled interest rate of 20% (the minimum necessary for viable credit provision to African smallholders) is prohibitively high. In the base case, none of the three poorest household types (#2-4) ever grows any hybrid maize. Access to dedicated credit (an unlikely eventuality, given their poverty, small transaction sizes and perceived lack of creditworthiness) would be necessary for them to bear the capital costs associated with HT maize. Household type #4 (poor, female-headed households) requires credit *plus* either the lower technology premium or the higher yield premium to adopt HT maize.

Adjusting the technology premium (10% instead of 40%) makes only a modest difference to adoption. Inelastic demand could encourage technology companies to set the premium quite high or to raise it quickly after an initial promotional period. Meanwhile, a higher yield premium would elicit an additional adoption response (replacing some traditional maize varieties) primarily from the two main surplus producing households (#5,7).

Impacts of HT Maize Adoption

Table 5 shows first-round maize production responses under the different modelled scenarios. Production increases under all scenarios due to the assumed 10% yield premium of HT maize over conventional hybrids. In scenario 1, the first-round maize production increase is modest (3%), but this translates into a major increase in net surplus from the Kasungu area, with undoubted maize price benefits for consumers both locally and nationally. Four household types remain net deficit in maize under scenario 1. Under scenarios 4 and 6, this reduces to one type (#6), which has regular wage income, so chooses to buy in maize rather than devoting household labour time to its production.

Table 5: Output Expansion Results

		Increase over base case (%), by scenario:					
	Base	1	2	3	4	5	6
Total maize production (tons)	620125	3%	13%	4%	17%	27%	44%
Net maize surplus (tons)	21499	73%	394%	118%	506%	782%	1276%
Household types that are net maize deficit	#2-4,6	#2-4,6	#4,6	#2,4,6	#6	#2,4,6	#6

Production of other crops does not change dramatically as a result of the introduction of HT maize. With access to credit for HT maize (fungible across other inputs in the model) household types #2 and #6 increase tobacco production, but type #5 reduces tobacco production under scenario 6. Given the high share of total household income acquired from off-farm sources plus the modest changes to cropping patterns as a result of the introduction of HT maize, total household incomes do not change substantially under any scenarios. Even under scenario 6, household incomes only rise by 3-4% for the less-poor households and 1-2% for the three poorest.

The main advantage of HT maize is the reduction in labour use during the main cropping season. The gross margin for HT maize is less than that attainable from competing hybrids, but households compensate for this by hiring out more labour in the November-January period, as a result of which the share of non-farm income in total income rises slightly. Under scenario 2, household types #2 and #3 accept a 1% fall in total income for the year in exchange for higher income in the November-January period, which is a time of greater hunger and the cause of distress in poor households in Malawi.

Thus, the seasonal labour market impacts of HT maize adoption are significant. In scenario 1, hiring out of labour during November-January increases by 12%, whilst hiring in by household types #5 and #7 is reduced by 37% (from a much lower base). Conversely, there are two sources of increased labour demand in the harvest and post-harvest periods: increased harvesting labour due to the yield premium from HT maize and greater demand for non-tradable goods and services in the local economy resulting from the modest income increases from HT maize adoption. In the credit scenarios (2,4,6), but not in the others (1,3,5), these latter increases are larger in man day terms than the net increases in hiring out during November-January.

There is a basic result that HT maize could be adopted and generate significant increases in output, up to about 40%, but there is an important caveat that shows how careful modellers must be. If we allow for the effect of the increase in labour availability and re-run scenario 1 with a 10% wage fall in the November-January and a 10% fall in maize price in the harvest and post-harvest periods, both adjustments discourage HT maize adoption. Indeed, they could be sufficient to wipe out the output response, unless policies such as employment in improving the rural infrastructure are put in place to keep wages up and also provide the cash for poorer household to buy GM maize.

The final message at present is that releasing HT maize without appropriate policy support may have a negative impact, but it does provide the opportunity to increase activity. The opportunity is two edged because it is the labour saving trait of HT that drives adoption, as it allows increased off farm work for wages at the most stressful time of year. But, if the increased labour supply is allowed to drive wages down and reduce maize prices, it chokes off adoption and leads to almost no gains.

ACTIVITIES

The conference papers and presentations are available at:
http://www3.imperial.ac.uk/environmentalpolicy/research/researchprojects/gmcrops

We have presented papers from this project at three very different venues:

Gouse M, Piesse J, Poulton C and Thirtle C, *Efficiency and Employment of GM Maize Producers in KwaZulu Natal*, a paper presented at the 12th International Consortium on Agricultural Biotechnology Research (ICABR) Conference on The Future of Agricultural Biotechnology: Creative Destruction, Adoption, or Irrelevance? Ravello, Italy, 12th -14th June, 2008

This is the only international agricultural biotechnology conference regularly attended by economists, so it was always part of our plans.

Gouse M, Piesse J, Poulton C and Thirtle C, *Factor Endowments, Biased Technological Change, Wages and Poverty Reduction: Can Genetically Modified Crops Bring a Green Revolution to SSA?*, a paper presented at the Harvard International Institute for Advanced

Studies Workshop on African Agricultural Development, Improving African Agriculture for Accelerated Growth, Accra, Ghana, September 5th – 6th, 2008

This gave us a route into West Africa, with the Harvard connection, and was unplanned opportunism. See the outputs section for the forthcoming publication.

Gouse M, Piesse J, Poulton C and Thirtle C, *Efficiency and Employment of GM Maize Producers in KwaZulu Natal*, a paper presented at the 46th annual Agricultural Economics Association of South Africa conference, "Rethinking Agriculture and Rural Development in Southern Africa", 24th September to 26th September 2008, Windhoek, Namibia.

This is the annual meeting of the local agricultural economics society so it was planned.

Gouse, M., Piesse, J., Thirtle, C. & Poulton, C. (2009). The Case of Bt Crops in South Africa. An IFPRI Conference: Delivering Agricultural Biotechnology to African Farmers: Linking Economic Research to Decision Making. To be presented at Imperial Resort Beach Hotel, Entebbe, Uganda, May 19-21, 2009

Links into the CGIAR activities

Some results are also reported in:

Jenifer Piesse and Colin Thirtle, Prospects for Agricultural Productivity Growth: Will there be a Slowdown in Developing Countries? Paper to be presented at OECD, Paris, April 7th.

Outputs

Journal Articles

Gouse, M., Piesse, J. & Thirtle, C. (2006) Output and labour effects of GM maize and minimum tillage in a communal area of KwaZulu Natal. Journal of Development Perspectives. 2:2, 192-207

Early results for the maize project.

Thirtle C and Piesse J (2007), Governance, Agricultural Productivity and Poverty Reduction in Africa, Asia and Latin America, *Irrigation and Drainage*, *Special Issue on Poverty Reduction*, 56:2-3, 165-177.

This paper adds governance variables to the explanation of $1 per day poverty reduction.

Thirtle C and Piesse J (2008), Genetically Modified Crops, Factor Endowments, Biased Technological Change, Wages and Poverty Reduction, *International Journal of Biotechnology*, 10:2/3, 184-206. Special issue on the Economics of Agricultural Biotechnology: An Overview, edited by R M Bennett, B Shankar and C S Srinivasan.

This is the publication that reviews the background work: see the forthcoming book chapter too.

Gouse M, Piesse J, Poulton C and Thirtle C (2009), Assessing the Performance of GM Maize Amongst Smallholders in Kwazulu-Natal, South Africa, *AgBioForum*, forthcoming.

This is the results of the first year's data.

Gouse M, Piesse J, Poulton C and Thirtle C (2009), Smallholders GM Maize in Kwazulu-Natal, South Africa: Results from a Panel, *Agrekon*, forthcoming.

This paper is the first results of the two years of data analysed together.

Book Chapters

Gouse, M. (2007). South Africa: Revealing the Potential and Obstacles, the Private Sector Model and Reaching the Traditional Sector. Chapter 10 in The Gene Revolution: GM Crops and Unequal Development: Edited by Sakiko Fukuda-Parr. Earthscan Publishers, London, ISBN-10 1844074099.

Gouse M, Piesse J, Poulton C and Thirtle C, *Factor Endowments, Biased Technological Change, Wages and Poverty Reduction: Can Genetically Modified Crops Bring a Green Revolution to SSA?(2009).* Chapter in Emmanuel Akyeampong, Robert Bates, and Daniel Obeng-Ofori, Improving African Agriculture for Accelerated Growth, Indiana University Press, forthcoming. Also to be published in Ghana by Woeli Publishers.

Gouse M, Shankar B and Thirtle C (2008), The Demise of Bt Cotton in KwaZulu Natal, Chapter 4, in William G. Moseley and Leslie C. Gray (eds), *Hanging by a Thread: Cotton, Globalization and Poverty in Africa,* Ohio University Press.

Report to Biosafety Authorities

Gouse M, Van Der Walt W and Kirsten J (2008), Bt Cotton and Bt Maize: An Evaluation of Direct and Indirect Impacts on the Cotton and Maize Farming Sectors in South Africa. Report commissioned and funded by the South African Department of Agriculture. Directorate Biosafety. Pretoria

Impacts

The South African GMO regulatory authority takes into consideration socio-economic issues during the decision making process on whether certain GM products should be given commodity clearance (imported) or should receive a general release (commercial production) permit. *Ex ante* assessments that inform the decision-making process tend to be based on rather hazy assumptions. We have assessed *ex post* the actual impact of the release of both Bt and HT maize. Findings of the ESRC study have already been used in a study commissioned and funded by the South African Department of Agriculture focusing on Bt crops (Gouse, Van Der Walt and Kirsten, 2008). This ESRC study will also supply crucial information to the South African regulatory authority on the actual impacts of herbicide tolerant crops and serve as reference document to new *ex ante* studies.

Also, our colleagues at Pretoria will go back to especially Hlabisa this year and tell the farmers what we found – as they do after most of our surveys.

Future Research Priorities

Ruttan (2002) was still unsure as to the future factor saving biases in SSA. He raised the possibility that, "even relatively land abundant countries, in Sub-Saharan Africa for example, will because of failure to develop a strong inter-sector labour market, end up following the East Asian biological technology path". We began our proposal wanting to find out if a labour saving technology could be significantly output-increasing in countries where there is no shortage of marginal land. Clearly, land saving technical change seems to make no sense and yet this is all that has ever worked well at the lowest levels of development. The Malawi household model gives sensible results and answers questions being asked in South Africa, so our next step has to be to look for funding to build a similar model for South Africa.

References not listed above:

Dorward A (2006), Markets and pro-poor agricultural growth: insights from livelihood and informal rural economy models in Malawi. *Agricultural Economics,* 35,157–169

Hayami Y and Ruttan V (1985), Agricultural Development: An International Perspective, Revised Edition, Baltimore: Johns Hopkins University Press

Shankar B, Bennett R and Morse S (2007), Output Risk Aspects of Genetically Modified Crop Technology in South Africa, *Economics of Innovation and New Technology,* 16:4, 277-291

Suhariyanto K and Thirtle C (2001), Productivity Growth and Convergence in Asian Agriculture, Journal of Agricultural Economics, 52:3, 96-110

Thirtle C, Beyers L and Piesse J (2003), Can GM-Technologies Help the Poor? The Impact of Bt Cotton in the Makhathini Flats of KwaZulu-Natal, World Development, 31:4, 717-32