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ROBERT TOWNSEND: Welcome, everyone. Try to start on time. Are there any questions from last time? OK, we'll take a look at the class syllabus. We did a theory lecture on Walrasian equilibria and 2x2x2 trade models in theory, last class. Today, we're going to begin the first of two applications of that. You can see, in fact, on the reading list the papers for today, which includes this thing with my Thai colleague, Archawa, which is taking the theory model back to the Thai applications.

And there's an additional stared reading here, Dawkins, which is calibration, which we have done before with the medieval villages and dynamics. And today, we're going to do it again. But that start reading does not appear anywhere, particularly in the lectures. But still, there aren't a lot of new theorems and stuff in the lecture today, mostly concepts. So I think you can get some time to look at the Dawkins starred article.

And on the class schedule-- so after the trade lecture application today and the one next Thursday. And then the following week, on Tuesday, I'll conduct with you a review session of the material covered in the last 1/3 of the class. So that's the way the schedule looks. Again, let me ask if there are questions. Otherwise, I'm going to turn to the study guide and, in particular, the material from last time lecture 13.

So the first review question was, in addition to reviewing what it takes in general equilibrium terms to describe an economy, what additional features do we need to put in there to describe a private ownership economy? And let me see if-- Dixon, do you want to take a stab at that?

AUDIENCE: Yeah, so for general equilibrium [INAUDIBLE] we need like the consumers' like preferences and consumption set, the firm technology, which is the production set, and then economy resources, which is endowment. But additionally, for the private ownership, each consumer has their own endowment. And also, each consumer has a complete ownership of the firm. So the firm is made out of consumer ownership.

ROBERT TOWNSEND: Good, OK. Yeah, each consumer has shares in firms. So those were the theta ij parameters. So if there are profits, as in decreasing returns to scale, those profits get distributed back to households. So they own the returns on the firm. So that's a great answer. Thank you so much. What is the potential difference between a Walrasian equilibrium and a price equilibrium with transfers? Maria Sofia, do you want to try that one?

AUDIENCE: Yeah, so with the price equilibrium with transfers, we're looking to see if there exists some assignment of wealth levels such that the economy will satisfy a set of constraints. But in general, a Walrasian equilibrium is a type of price equilibrium with transfers, except we have the condition that the wealth is equal to-- I think it's the price times the wealth plus the sum of the profits over the shares that the consumer has in various companies.

ROBERT TOWNSEND: Yes, that's right. So the Walrasian equilibrium works off of this private ownership economy. So we have the valuation of the household's endowment plus the valuation of the profits that the household has a claim to. And that is a wealth object. So technically, it looks like a price equilibrium with transfers, meaning that if we assign that particular wealth, we're going to have an equilibrium.

The more general idea behind the price equilibrium with transfers, though, including the transfers part, is that the wealth assignments that we give to households may be greater or less than the valuation of the wealth they would have if we had restricted ourselves to private ownership. So what I didn't, I guess, emphasize very much is there are going to be two welfare theorems that we will study in detail.

One is that the Walrasian equilibrium is pareto optimal. And for that part, we need private ownership only. And the second is going to be that any pareto optimal allocation can be achieved with the suitable redistribution of wealth. And that's the part where we're going to need this more general concept of price equilibrium with transfers.

The ordering of the class was to introduce this Walrasian equilibrium notion, not dwell on the optimality of it, but rather get into some applications and then. In a couple of weeks, we'll be back to those welfare theorems and when they are true and when they can fail. So that's the ordering of the class.

And we got into the 2x2x2. All of this stuff at the beginning is kind of a review of the notation, where we have minimizing the cost of achieving a unit output, given the vector of factor prices w. And we had the cost-minimizing input values. And at the end of all that, I finally got around to asking, define what it means for the production of good 1 to be relatively more intensive in factor 1 than the production of good 2. So [INAUDIBLE] see if we can get some-- how about a volunteer for that one?

AUDIENCE: I can take this one. Yeah, so this means that for producing a unit of good 1 versus a unit of good 2, you need the ratio of factor 1 to factor 2 that's used to produce one unit of good 1 is greater than the ratio of factor 1 to factor 2 in producing a unit of good 2.

ROBERT TOWNSEND: Excellent. Perfect answer. And then implicit, let me just add a little bit editorial, which is, it's defined over the whole domain. So whatever those factor prices are, w1 in w2, it remains true that good one uses relatively more factor 1 than factor 2 and vice versa. So it's a statement about the whole-- and we used that in the analysis in class, when we were looking at the cost curves and what would happen if input prices moved. Can someone take a stab at the Stolper-Samuelson theorem for the determination of input prices as output prices change?

AUDIENCE: I can.

ROBERT TOWNSEND: OK.

AUDIENCE: In this theorem, we assume that the model [INAUDIBLE] to modify [INAUDIBLE] then when the output price, like the price of good 1, increases, then the intensive factors in producing the good 1 also increases. And another factor, factor 2, that was not the intensive factor [INAUDIBLE] the price of this factor world goes down. Yeah.

ROBERT TOWNSEND: OK, that's good. Yup. So nominally, it's not a statement about international trade, although it is very useful in that context. We're just basically doing some comparative static exercises of what would happen if these exogenously given output prices are changing. What's going to happen to input prices? And then we did a graph. We used those cost curves to illustrate it. I flagged the last question, but I really don't want to ask that one. I want to ask something a little harder to answer.

If we had two countries, and each country had a representative consumer, and there are two goods, each of which can be produced in both countries, and there were two factors that can be used in each good in each country, we've got a lot of equations and unknowns. We've got the consumers' consumption levels of the two goods, the input being used to produce outputs of the two goods, the outputs themselves of the two goods, and the prices of each of the two inputs in both countries, et cetera, et cetera. Can someone tell me how we attack this problem in class, in the sense of an algorithm? We broke it into pieces. Otherwise, it's a very high-dimensional problem. If you remember the ordering--

AUDIENCE: [INAUDIBLE]

ROBERT TOWNSEND: Yeah, go ahead, please.

AUDIENCE: Yeah, I think that the way that we did this was kind of inductively, where I think that the way that we did this was, first, pretend, basically, that it's just like the original 2x2 model. And then we solve for the what's supposed to happen there. And then we built in the additional thing of-- I'm pretty sure we built in the different endowments, I think, was the difference in the 2x2x2 versus the 2x2. But we solve for the smaller model, and then we build it upwards to the bigger one.

ROBERT TOWNSEND: That's true. And what, in particular, did we focus on first in the smaller model?

AUDIENCE: I think the way that we did this was kind of the-- I don't think I remember this.

ROBERT TOWNSEND: OK, anyone else want to take an attempt at it? This is a difficult question to pose and hard to answer, because it has to do with putting the pieces a lot of information in the lecture and taking a step backwards and thinking about it globally. OK, well, it starts with this Stolper-Samuelson theorem. So at this point, early on in the lecture, we were taking the prices of the goods p1 and p2, as given. We weren't trying to solve for that. I had not yet introduced consumers either. We didn't even attempt to solve for the quantities. We merely wanted to find equilibrium factor prices.

So for a given country-- you could think of it that way, a given economy-- we had the minimized cost of producing one unit of good 1, the minimized cost of producing one unit of good 2. And that's in the space of input prices w1 and w2. So we're looking for an equilibrium. Therefore, the input prices should be the same regardless of whether it's good 1 or good 2. So we looked at where those curves crossed, and that's the only point in the diagram where we can both have common input prices of the two inputs and be on those curves, where the curves crossed.

So that was the very, very first part. And then given those prices, we moved to a different space, which had isoquants. So there, we have the unit output or any output, really, described by an isoquant, a different isoquant for different quantities, and we had the inputs on the x-axis. So there, we solved for minimizing unit cost again, but what's on the x and y-axis would be the input quantities. And we know that has to align with the factor prices we already solved for. So there, we determine both the input quantities as well as the output quantities, where both firm 1 and firm 2 could be in equilibrium.

And then, finally, at the very end of the lecture, we zeroed out to consider two countries, not just one, each with a consumer. And those countries could be in autarky or potentially trading with one another. Both specifications would be legitimate general equilibrium environments, both autarky-- each country separately is one-- and then we traded another, except, obviously, with trade, consumption and production do not have to be the same, because the countries can export one thing and import another.

Sorry, that's a rather long-winded summary. But again, it's not the easiest lecture, maybe potentially the hardest lecture in the whole series of lectures. So I thought I would take the time to elaborate a bit on what we were doing. OK, so that's the review. And we come to applying a very similar theory to actual data.

So this is real and financial flows in Thailand and an outline. We're going to talk about villages again, but we're going to embed them in the local economy and also their relationship to the national economy, where we view the financial accounts, which you've seen once before when we did the Bitcoin part. We'll review them here-- balance sheets, income statement, and cash flow-- then more general background on these village economies and heterogeneity within them. Then we'll take the village economy, as an entire economy, and come up with GDP and village income, the way we come up with national income and the National Income and Product Accounts.

And then, finally, as a small open economy, we can look at flow of funds, balance of payments, how open or how closed is the economy. And then we come to this calibration part, which I already highlighted, with respect to the other starred reading, Dawkins et al. What does it mean to be calibrating a model, which they often did in the trade context, as we do here? And we'll look at model-predicted data and compare it directly to actual data and then look at some counterfactuals, like imposing tariffs and frictions.

So last time end today, you could think of this question as, free trade, who are the winners and losers, tariffs, who are the winners and losers, and not in the abstract, as in last time, but actually here, in the context of a calibrated model. You'll actually see the impact on individual people living in these villages. And then when we get to the US, we'll do it all again on Thursday, which is a different context, but the same kind of theory.

OK, so you've seen this before. Let me highlight the time map. We have these two provinces, Chachoengsao and Lopburi in the central area of the country, near, if not right on top of, Bangkok. And we have the other two, Buriram and Sisaket in the Northeast, a much more agrarian area of the country.

This is Sisaket. I muttered something about not finding these monthly starred villages, but I knew where they were. And now I realize it's still very hard to read. But these Cheerio circles correspond to baseline survey done in 1997. A subset of those villages were chosen from '98 onward, including the data that we're using. In which case, it's a monthly survey. So the Cheerio covers up the star and produces these green-like objects up here. So that's the cluster. So there are four villages in Sisaket that constitute the monthly data. And likewise, there are going to be four each in the other three provinces.

OK so let's take Lopburi over here, and take a wage earner, and look at this actual household's income statement. So you've seen version of this before, and I remember asking you about it in the follow-up. We've got revenues and costs. In this case, this guy does a little bit of livestock, but mostly, it's wage labor. And in principle, could have had interest income, but didn't. And on the cost side, most of these costs are associated with livestock and in debt and actually has an interest expense, and then does consumption and subtracts that off of income and has some savings. So that's the income statement of household A, which we have these kinds of statements for roughly 800 households.

Here's what happens over time. That labor income, which is the dominant source of income, falls and then gradually increases back up again. Other components are largely zero, although they started the business in the last year or two. Cultivation rises and then falls again. So trying this, that, or the other, but largely labor income.

This same household has a balance sheet, which has liabilities on the right-hand side and assets on the left-hand side. Since those things don't balance, hopefully liabilities are smaller than assets, and the difference is net worth. So we have liabilities and net worth on the right-hand side and assets on the left. Assets consist of financial assets like cash and could have been a little bit of deposits in banks. And those are financial assets, and then we have real assets like livestock and so on, inventories, and we have other fixed assets, including household assets, OK?

And you're wondering where I'm going with this. I'm deliberately highlighting things that are going to come up momentarily. And again, the balance sheet over time for this household, you can see wealth is going up, mostly because assets are going up. But toward the end, when the household started that business, they borrowed. Liabilities went up, and net worth actually went down. But anyway, this is over time.

Finally, we have the statement of cash flow, which I highlighted when we talked about Bitcoin. We've got cash flow from production and cash flow from financing investment and consumption, and that produces a measure of cash flow from the flows, which has to sync up with the change in the cash and the balance sheet, which it does in these data.

So next, I want to talk about diversity across the households, especially for the ones who are actually firms, who have decided to go into business. The types of activities, cultivation, farming business like retail outlets, trucking stuff around livestock, fish and shrimp. And this is like a Cobb-Douglas production function written out in logs. So delta k is the intensity of the capital good, and delta l is the intensity of the labor good. And what we want to see are those factor intensities.

So in fact, if you look, cultivation is labor-intensive. It will fit the definition we reviewed at the beginning of class. Uses relatively more labor than capital because of the coefficients delta l and delta k. On the other extreme, the fish and shrimp uses almost no labor at all and uses tons of capital. So we've got capital and labor-intensive activities. We can try to make it simpler and talk about basically agricultural goods versus others called manufacturing. It really means non-agricultural.

OK, the other thing sitting up here is this epsilon. This is quote, "an error term," but it actually contains not just noisy data, but a measurement of talent. So if we took the average for a particular household i, we took the average of these epsilons, they don't have to average out to 0. They average out to something that is common to the sector that household i has engaged in, a bar, and some other household-specific talent called z, OK? So there's a sector and household-specific talent variable that's wrapped up into these epsilons. Obviously, if you're talented, the epsilons are going to tend to be high, meaning output is going to be high, even controlling for capital and labor.

So if you looked across the sectors at, quote, "sectoral productivity," they are pretty similar. The highest one here is livestock, the lowest one is business. Now, in terms of the household-specific productivities, there's a whole cross sectional dispersion of these zi's in each sector. And so this sigma is a characterization of the-- a bit like a variance of the distribution. The point being that each household has a particular z depending on the sector in which they reside, and they could be very talented or not talented at all, even though they're engaged in that activity. And these are estimated in the data. You're looking at the actual numbers.

The other aspect of heterogeneity here, in addition to household talent, would be their wealth or, specifically, their fixed assets. That's why I emphasized it when we went through the balance sheet. And you can see the cross-sectional distribution in Lopburi, which is near Bangkok, versus the cross sectional distribution in Buriram, which has a lot more mass over here to the left, meaning low assets. So indeed, in the data, Lopburi near Bangkok has higher average fixed assets than does Buriram out in the Northeast.

But again, it is the whole distribution. So a given household could have relatively little wealth or have a lot of wealth, even in Buriram. This actually is consistent with the Pauson, Townsend, Karaivanov paper, which was an application of mechanism design, where we talked about the talent of being a firm. Theta, I think, we had it there. And also, we talked about assets separately. And indeed, we talked about a limited liability constraint, which is coming up.

So we have this cash thing, which, as I was saying, from your previous lecture, you know cash holdings don't behave very well. So we just impose what we see in the data, that cash holdings, that part of wealth that they're putting into cash, is fixed. It turns out that consumption is related to that. We imposed that consumption is equal to an intercept plus profits less that intercept. And gamma here has to do with omega, which is the fraction of savings that put into cash. I didn't put the algebra in, which I probably should have done, except all I want to say from this is the cash part of savings is just fitted to the model. It's not something we derived.

So now I want to go back to those accounts and show you where gross national product comes from, except that, in this case, it's going to be village-level product and income. And then we'll go on to flow of funds, the balance sheet, balance of payments, and so on. So the top you've seen before. That's the statement of income, revenues less costs, but now we start subtracting things from both sides. For example, to get rid of capital gains, capital losses, and indemnity, we subtract them off, and then they appear with the opposite sign on the left-hand side. Likewise, we have expenses from production, which we subtract off of both sides. Hence, it disappears on the left hand side and reappears on the right, and it's subtracted.

So we end up with revenues less expenses in production, which we call output. And on the left-hand side, we have the disposition of output. Output is used to pay interest. It's used to pay interest for capital. Normally, you would see wages paid to labor over here, and I'll come back to that momentarily. And the residual is profits.

So all output gets paid, in the sense of paying hired factors or what's left over accruing to the business owner. So this is a classic decomposition of the national income accounts, from production or from inputs. We're really interested in international trade, so we're really interested, here, in how much is labor getting paid, how much of the interest being paid to capital, and so on as a function of output, just a bit like the 2x2x2 lecture.

So if we're looking at output, remember, there are four villages in each province that were selected for the monthly data. Here, you can actually see output going down in Chachoengsao-- wiggling, but going down-- whereas, in Buriram, output is going up. And these are the other two provinces. So another point to make is that output is different across different villages, even though they're nearby to one another.

And also, you'll miss it if I don't point it out, probably, which is the scale in the Northeast, the maximum value is 6 and 5, whereas, in the central, the maximum is 15 and 12. So yeah, villages near Bangkok have higher output than villages in the Northeast, but there remains heterogeneity across the villages, and you see the ups and downs.

The shrimp ponds got hit with a bad shock that we've talked about previously in the network lecture under risk-sharing. So that's part of the decline in output in Chachoengsao. Buriram used to be a bunch of villages. We put rain gauges out there to measure waterfall and so on. And then it experienced a boom, and those villages were subsumed by the town. And you can see that expansion pretty dramatically in this output diagram.

And as I was saying, we can decompose output into who gets it. And you can see here, wages, which is the darkest line, is the bigger part of the disposition of output in Buriram. In Sisaket, wages are not as much-- they're not trivial near Bangkok-- Chachoengsao and Lopburi. Instead, we have these two sectors, the labor-intensive agricultural sector and the capital-intensive manufacturing sector as sometimes having profit shares which are higher than the wages.

Now we come to the savings investment account. We take the balance sheet at a point in time, and we take the first difference. So now we'll have the change in liabilities, the change the net worth on the right, change in financial and real physical assets on the left. We now go through this thing about subtracting items on the left and the right-hand side. We leave the change in net worth on the right-hand side and the disposition of that change into an increase in financial or real assets or a decrease in liabilities. So we can see they're managing their portfolio, in an accounting sense, as a function of, what do they do with savings. And likewise, if savings are negative because they consume more than they earn, then they have to draw that value out of something or borrow.

So this is the allocation of savings across the four provinces. The darkest line here is savings, which is largely going up, although not entirely. Savings is going down and Chachoengsao, as you might have expected, since they got to finance those losses, that declining output from somewhere. They're preserving consumption by taking it out of savings. Likewise, they can save in the fixed assets, save in the financial assets.

The thing that tracks the best overall-- tracks dark savings overall, the best-- is financial. And you can see in most of these diagrams, the black dotted lines are close to the solid black line. So financial assets increase when savings is positive, but these other real and physical stuff as well as gifts play a role.

Gifts are not trivial in these economies, as you already know from thinking about insurance and so on. So all these things add up. Gifts, financial transfers, inventory, and so on add up to savings. But gifts could be negative, because they're not incoming, but they're outgoing. They're not saving it. They're giving it away. It's not always negative. Gifts are positive, in some instances. But in any event, they're not a trivial order of magnitude, and we will look at that subsequently again.

In terms of financial flows, you've got something called the current account. For the US, for example, are they running a trade balance, or are they earning money from abroad? And likewise, for these villages, they export and import stuff. We take the trade balance as the difference if positive. Exports exceed imports. And likewise, some member of the household is in Bangkok and earning money and sending that money back home as a gift, that's factor income earned abroad. In China, people work in the Philippines and send money back home. So this is called the current account.

Now, there are corresponding items, offsetting items, on the financial account. Basically, if you're running a trade surplus, you're acquiring claims on foreigners, which could be by holding their currency, holding their financial assets, or holding their real assets. And as we'll talk about next time, the US has been running a trade deficit with China, which means China is acquiring claims on the US, holding US treasuries, real estate, and so on. So the names change to protect the innocent, in the sense of we're not looking at countries here. We're looking at villages, but we're doing all the accounting for the villages the way it's done for countries, with exactly the same accounting identities.

And the point of all of this is only to tell you where some of these things that you've heard of are coming from. From the ground up, from each and every household, we have the financial accounts-- income statement, balance sheet, and so on. We can add it up over all households in the village, as the sample allows, and get the village-level aggregates. This is for all of Thailand. Thailand was running a trade deficit, and foreigners were acquiring claims on Thailand until the 1997 financial crisis, in which case, things reversed. And they've been a bit unstable ever since.

In this case, balance of payments are roughly a certain of GDP, maybe 10%. That's a big number. It's typically 5%. So when we come to villages, you might ask, how big are these flows? And the answer is, typically, much bigger. For example, in Chachoengsao, the balance of payments, including the trade and the current account, can be as high as 20% of GDP. And Lopburi, likewise reaches 15% of GDP.

So they are small open economies. These villages are engaged with the rest of the country. And in fact, we can break that down into the gifts, which I showed you a moment ago, as well as, here, the measure of openness in terms of trade, which is exports minus imports. So roughly, Chachoengsao near Bangkok, its imports and exports are almost matching one another. Whereas, out in the Northeast, the imports are a lot bigger than the exports. The imports are for production. They're inputs acquired for production, and they export a little bit of their output. They eat a lot of the rice that they produce and export less.

I'm getting ready to show you the model. One, what about the relative price? At the beginning of this class, we talked about the price of good 1 the price of good 2. We have two sectors for simplicity, agriculture and manufacturing. So from the data, we can actually see, overall, that the price of the agricultural good is going up, the ratio is going down, from the standpoint of a typical village, with the possibility of imports and exports, just the way we had countries possibly exporting and importing to each other.

In terms of the factor prices, remember the minimized cost curve? Well, this is over time. So we can see the wage rate and the interest rate, both adjusted to be in units of consumption. Hence, real values as a numerator. So in the areas near Bangkok, the blue and the red, we can see that wages tend to be higher than they are in the Northeast. Now, near Bangkok, you would think this is relatively capital-abundant, because they're pretty industrialized and short of labor. So indeed, the relative price of labor to capital is higher in the areas near Bangkok, reflecting the capital abundance and the relative shortage of labor.

The reverse is true in the Northeast. And also, we can look at the interest rate, which is like the price of capital. And again, you can see that now the blue and the red are at the bottom, because places near Bangkok are capital-abundant. And so the interest rates tend to be low. We did this experiment for the Heckscher-Ohlin model. Countries that are relatively abundant in a factor should be exporting the good which uses that factor relatively intensively.

So you can imagine that places near Bangkok that are abundant in capital will have a tendency to export the manufactured goods, because that's the one that's intensive in capital. What am I doing today? I'm just getting the labels to be realistic in actual context, realistic relative to last time. We learned the theory first. Now we're applying it, although with some modifications.

The other thing you can see here is the interest rates are converging. They're getting really close to one another over time. So one imagines that if they could [INAUDIBLE] trade in inputs. Not just outputs. It's pretty easy to do that with a capital input. But the wage rates are not converging, so that's also a hint that, like the 2x2 model, we're not going to allow labor to be moving across borders.

OK, so I'm going to show you the ingredients for a small open, economy and then I'm going to tell you what the difference is with a 2x2x2 that we did last time. So it is 2x2-- 2 goods, 2 factors-- although it's a village relative to the rest of the country. Different from last time, we're going to have financial frictions, like those borrowing-to-wealth ratios.

There's a lot of agents in each village, and they differ in their wealth and ability levels. They can choose to be workers or they could become a firm. And if they're an entrepreneur, they could be in the manufacturing or agricultural sector. So that's one of the two 2s-- two goods, agriculture and manufacturing, two inputs, capital and labor, with the factor intensities different.

Labor is owned by households and supplied inelastically, like it was last time. They get this wage w. Wealth is owned by households and supplied at an interest rate, but it's also changing over time. Unlike what we had last time, we've got dynamics in a way to save money over time. They can use their capital, or they can lend it out. So we have a borrowing and lending market, but that capital market is imperfect. Namely, you can't necessarily use an unlimited amount of capital k. You're bounded by your wealth. So that, for the third time today, is mention of the limited liability constraints.

So the differences with last time, we have decreasing returns to scale, whereas, last time, in the theory lecture, we used and abused the fact that it was constant returns to scale-- hence, unit costs of production, which scale up and down depending on the level of production. Factor mobility is somewhat limited here, but the capital good moves around, unlike last time. We have financial variables here and real variables, whereas, last time, we only had real variables. And likewise, here, we have borrowing constraints. And last time, we didn't have any of that.

But this model does have the different endowments of the factors. It does have the different factor intensities. It keeps the 2x2x2-- well, 2x2 anyway with small open economy. And so part of what you're going to see in the simulations reflects what we learned last time. And part of it is a bit different, because it has a few additional realistic features.

Rather than take you through the entire model, I'll just give you the notation at the beginning. Each entrepreneur can produce sector a, which could be agriculture, but it's also manufacturing. A household has a certain talent level z and an initial capital stock. It will use its inputs, capital and higher labor, at its productivity level, selling it for the price of output. But it has to pay input costs for capital and labor, and the input prices are r and w.

So you've seen this many times. This is just a statement of profits for a firm. It happens to be a firm owned and entirely operated by a given household, because the theta ij equals 1. And here's the borrowing constraint. Capital utilized is limited by the pre-existing stock of fixed assets [INAUDIBLE] this constant c could be greater than 1, which allows them to borrow, to acquire fixed assets and production greater than what they already own.

Labor is non-negative. As in that paper with Anna Palson and Karaivanov they could choose to be a wage earner, put all their wealth-- lend it out, basically, earn interest on it, or they earn money from being a wage earner. Likewise, we have profits for agriculturalists and manufacturers. And they're, in principle, lending stuff out, but they could be borrowing some of it back to finance production.

And then we have a utility over consumption of agriculture and manufactured goods, which looks this Cobb-Douglas thing, where these etas are cleverly chosen to allow us to talk about aggregate savings. Because, in fact, there's capital in manufacturing and capital in agriculture, and we don't want to keep having to refer to the distinction about where they're saving. So we come up with this ideal price index. Don't worry about it too much. It exists. That's all we need to know.

OK, it's a small open economy. Households have their capital endowment. We fit a distribution that fits pretty well, relative to the histograms I've already shown you. We have the labor endowments. We know how much time they have. We give them a little bit of sleep and come up with how many units of labor they can supply over the year, which is fixed and exogenous. Then they have a savings rate. Which, again, as I already said, that was an omega. We fit to match the data.

I mentioned that, in the context of the cash holdings, one could imagine having these households solve discounted expected utility maximization problems over their lifetime that adds a lot to the complication. So instead of doing that, we just basically impose from the data onto the households an estimated savings rate.

Now, this is a kind of interesting diagram, because all these parameters, like the factor intensity numbers and everything else, are going to be calibrated, which I'll tell you about momentarily. And we will generate pictures like this. So I mentioned the calibration, only because you can draw any picture you want. But this is what it's going to look like after the work is done of estimation. Over here, we have low-wealth households versus high-wealth households. The other dimension of heterogeneity is low talent versus high talent. And you can see if they're not very talented, they're not going to go into either type of business. They're going to be workers.

On the other hand, if talent reaches a higher level, they could decide to go into manufacturing or agriculture. And then for a given level of wealth, they may be constrained or unconstrained. Ironically, the more talented they are, given a certain borrowing constraint and their wealth, the more constrained they're going to be, because they would like to do more and they're not allowed to do it. And here, it actually moves from being constrained in manufacturing to being constrained in agriculture. So it's the really, really talented guys who are sticking on the farm, given the parameters that we estimated.

This I've already said. We're going to have an open market for capital, but a closed market for labor. And again, that's because the interest rates are converging. So it looks like, in the end, at least, capital can be moved across provinces without a cost. Here's, finally, the calibration slide. We have to figure out the relative prices. We need the interest rate. We're going to take it as exogenous. The relative price of manufacturing versus agriculture we're going to take as exogenous and match it up with what we see in the data as exogenous. I'll come back to how we pick it in a minute. And the borrowing rates are exogenous.

We stick in, for the interest rate, what we observe in the data. We don't know about this relative price of the borrowing limit, but we do have the profit sharing in each sector. So we move the relative prices to match the profit share. So for example, if agriculture has a price pa and we observe a large relative share of profits from agriculture, then we imagine that it's a relatively high price of the agricultural goods relative to the manufacturing goods and vice versa.

Likewise, we're going to move the borrowing limit to match the observed wage rate. The point being that if they can't borrow very much, they're not going to have a very high scale of production. They're not going to hire a lot of labor. The demand for labor being low means the wage that has to clear the local market is going to be low.

The bigger picture here is calibration. You have objects that matter a lot in the model. And how you pick them, well, here, we pick them by taking the data that we have and varying the parameters in the model in such a way that we can fit the model-generated data to the actual data. Doing that, we have to make a choice of which part of the actual data to use to calibrate which parameter. And again, read the Dawkins thing, and you'll see a discussion of this much more generally.

OK, so let's look at what happens. How well are we doing? Oh, these economists, they come up with these models. God knows how well they predict, so I'll show you how well we're doing. This is, at the calibrated values for Lopburi, I believe-- doesn't say that on the slide-- the actual level of output and the predicted level of output-- model-predicted. So we ran a successful experiment. If you think about the model as an experiment, populated by the parameters we calibrate, then we are able to take this stylized model, a la Lucas, and use it to interpret reality.

This is pretty close for consumption, the actual being below the model. So in this case, they're consuming a little bit less than what the model says they might, despite our attempt to fit it to the data. And this is for assets, which is very, very close. Now, these last three figures are all aggregated across all the households in a given economy.

OK, so having sort of-- oh, and this is cash holdings, which is one of our weak points. And we're pretty close for a while, and then cash holdings in the data still want to be higher than in the model. God knows why they want that cash. We're just still dumbfounded. That's the way they're saving over time, in the aggregate. Accumulating claims on foreigners? Yeah, that's the paper currency. It's a claim on the central bank, and they love. It doesn't bear interest or anything. But anyway, I'll stop complaining.

OK, so having done pretty well with the aggregates, one hopes we've earned the right to talk about individual experiences. Now, needless to say, there are many households in a village and a non-trivial number of households in the sample. We're fitting the aggregates via calibration. I wouldn't expect perfect performance for each and every individual. That's too much to hope for, but let me show you how well we did with household a, that labor household in Lopburi that we featured at the beginning.

So this is the actual darker line, labor income. I showed you this path before, actually, in wages. And they went into livestock a bit. They went into business and borrowed to do it. This is the actual model prediction, which is a lot flatter, but it's not that far off. It matches pretty well at the beginning and the end. This is consumption, which is horrible. So for this household, the actual numbers drop lower than what the model says it ought to be, and fixed assets is closer. We do pretty well with fixed assets, including at the individual household a level. And cash, again, under and over, going up, though, for both.

OK, so I'm tempted to put this in the US context, because it may make it seem more real if you haven't been in Thai villages. What's the effect on farmers of restricted exports to China, when China retaliated? They came to an agreement, but, still, China's not purchasing as much. The other way around, what about manufactured goods coming in from China? What's the effect on wage-earners that produce the thing, which is now being imported, whereas, before, had been produced domestically? But we're going to talk about those things next time, but we can already answer questions like this for Thailand. If, for example, we take the actual estimated model and run counterfactuals, OK?

So suppose we impose trade frictions within the country. What are tariffs going to do, basically? They hurt trade. So if a village had been exporting a lot of agricultural goods and importing a lot of manufactured goods, as in the Northeast, then the effect of a trade friction will increase the price of the thing that they have been buying, the import good, and decrease the price of the export good. Hurt both ways. We're going to do it by 1%.

So we're going to take these calibrated prices that were used to match the payments to factors and profits and now vary them and see what happens. We're also going to do a financial experiment in the model. We're going to change the interest rate. So it's like we're going to impede financial flows. So again, the effect of it always hurts. So if the village had been a net lender, for example, then the effect of the financial friction is to make the interest rate lower, because lenders don't like low interest rates. We talked about that when we did the lecture on income and price effects for households in the two-good world.

Anyway, so if they're lending, they're not going to it that the interest rate goes down. And likewise, if they had been borrowing, we would have gone the other way and make the loans more expensive. So that's the effect of the way we capture in the model, in order to run an experiment, the impact of trade frictions through tariffs and/or internal frictions and financial frictions.

So now you want to see what happens. This is in Lopburi, and this is the effect of that 1% increase in trade frictions, making exports give less revenue. Imports now cost more. That's going to affect the production and profits from the manufactured good and the agricultural good. And in turn, remember the algorithm from last time that I reviewed? Those price changes are going to map into-- input quantities are going to map into relative factor price movements, OK?

But there's a lot of diversity in these economies. As I've been saying, households differ by their initial level of capital. They differ also by their talent. So we have capital moving on the x-axis and the average skill level, pretty high skill level, and very high skill level. And then what's getting plotted here is the gains or losses. So it's a tariff, effectively. So you might expect losses. And in fact, these average or low skilled guys do suffer losses, arguably because they're wage earners, although you can see that. And the movement in production from the capital good and the labor-intensive good was such as to hurt the wage.

So remember, we did Stolper-Samuelson, where an increase in the price causes an increase in the factor price of the good that is used relatively intensively. So despite all the differences with the 2x2 from last time, that ingredient is playing a role here. So these wage-earners are hurt, initially. But then, ironically, as we move in the cross section for a higher level of capital, they were actually producers, not wage-earners. And now the lower wage helps them, because it's a lowered cost of production. So their profits go up. Now they're winning, by a little less than 1%. And if they're really, really talented, they'd been producing at a higher scale all along, so the drop in wages is even better for them.

OK, I'm trying to give you some intuition here, but I decided, because time was short, I wouldn't be able to actually prove all these assertions. I'm just asking you to imagine, from the 2x2x2 that we did last time, why it is we're seeing all this diversity here. The order of magnitude is, like, less than 1%. Here, it's 1%. So that's pretty small. But if you look at the financial frictions in Lopburi, in the sense that I described, you can see bigger numbers.

First of all, you see winners and losers. You also see that it matters whether they were wage-earners or capitalists. But above all, you see that the high-skilled guys can benefit up to 10% from the increase in the interest rate that's associated with the financial friction, because the village had been borrowing, but some of those guys don't borrow. They lend. And likewise, there are other people here, the average-skilled guys, who are taking big losses of up to 10%.

So again, one could imagine producing pictures like this. And if we go back to household a, what happens to a wage earner in the US with manufactured imports or a farmer in the Midwest with agricultural exports? What happens in Lopburi to that wage-earner under the trade friction or under the financial friction? They lose. He or she loses. That household loses.

So we validated the model to try to make this realistic. It fit pretty well-- very well. At the aggregate level, it fit pretty well. At the individual level-- so if for some reason the Thai government had run this experiment or they had political issues that made the country more isolated, you could see the effect of that on individual households through the lens of the model. OK, any final questions? So again, we'll kind of do it all over again when we come to the US next time, next Thursday.