Trade and the Environment. Linking a partial equilibrium trade model with production systems and their environmental consequences

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Abstract

The link between trade and the environment has aroused considerable interest in terms of both the impact of trade liberalisation on the environment but also the impact of environmental policy on production and trade. This interest is expressed at the global level, especially with the WTO round of negotiations, but also at the micro level where local government and agencies are concerned about the impacts of policies on production and trade, as well as the local environment.

As an example of economic analysis of these issues, this paper presents a partial-equilibrium model of international trade in dairy products. The trade model is based upon the model building shell VORSIM, but has been extended to include physical dairy production systems and their effect on water quality. This combined model is used to simulate the effects of various policy options on trade flows, dairying production systems and groundwater nitrate levels across different international trading partners.

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1. Introduction

Agricultural trade liberalisation and its potential environmental consequences are currently a politically emotive topic, as demonstrated by behaviour both within and outside of the inaugural Seattle negotiation meeting of the World Trade Organisation (WTO) in December 1999. Proponents of free-trade argue that continued liberalisation will deliver significant economic efficiency and therefore welfare gains as global resource allocations shift to better reflect international comparative advantages. Moreover, since much environmental degradation may be attributed to 'inappropriate' agricultural activities induced by market distortions, liberalisation will cause production and associated resource usage to revert to a more environmentally benign pattern.

In contrast, opponents contend that heterogeneity of environmental characteristics both within and between trading nations means that environmental degradation may increase locally, if not globally[2]. That is, since the assimilative capacity of the environment with respect to agriculture varies spatially, if production shifts geographically then the net change in environmental damage will depend partly upon the relative environmental fragility of the old and new locations. Moreover, rigidities in production structures mean that it is by no means certain that reducing market distortions will necessarily lead to more environmentally benign production patterns in locations currently experiencing degradation (Potter, 1996).

This is important to both Australia and New Zealand who face restrictions on market access. Trade liberalisation through the GATT have reduced some of the these barriers and policy developments indicate that these will further be reduced. However there is the increasing threat that non-tariff barriers to trade will increase especially those based upon environmental criteria. Therefore it is important that the impact of changes in trading conditions on production and hence the environment are identified and this as well as the impact of environmental policy on trade assessed.

Identifying the trade-off between environmental damage and economic efficiency gains across different trading nations is thus a pressing task. However, it is not a trivial task. Representing production and environmental heterogeneity requires careful consideration of not only the trade flows arising from international market and policy interactions, but also the production structures and constraints underpinning domestic supplies and (localised) environmental susceptibility to changes in both the levels and mixes of outputs generated and inputs used. This paper reports an attempt to build a modelling structure to do this for selected countries using the example of nitrate concentrations in groundwater and international trade in dairy products. The next section reviews briefly recent trade modelling literature and identifies the key modelling challenges. Section 3 briefly describes the international dairy situation and outlines the chosen modelling approach. Section 4 presents and discusses some results. Section 5 concludes with some further research questions.

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[2] Concern is also expressed about the likely unequal distribution of social adjustment costs across different groups and different countries (ref). Whilst this issue is often bundled with environmental concerns, it is beyond the scope of this paper.

2. Trade and environment modelling

Modelling the geographical distribution of the environmental consequences of trade liberalisation poses three main challenges. First, it is necessary to accurately represent international trading relations and policies in order to simulate the distribution of production (and consumption) across different countries. Despite progress made in the Uruguay Round, many barriers to trade remain in place and there has been an expansion of the relative importance of non-tariff barriers to trade e.g. tariff-rate quotas and preferential access agreements. The nature and operation of such measures typically varies between countries and in-itself complicates the modelling of trade flows (Meilke 1996)

Second, to simulate the impact of trade on the environment the impact of trade on output has to be estimated Moreover, the subsequent identification of associated environmental effects requires that these output levels be first translated into management practices and resource usage levels in each country, or regions within a country. This entails an understanding of production systems and structures and the data to accurately quantify them. Unfortunately, sub-regional data production data are often somewhat elusive.

Third the management practices and resource usage levels at different locations need to be translated into environmental damage. This requires (scientific) understanding of environmental conditions and relationships, together with the data to describe these.

Literature review

There are two generally used economic modeling frameworks which could provide the basis for modeling and analysing trade-environment links and broadly these can be classified under trade-environment focused partial (PE) and computable general equilibrium models (CGE). These models have been primarily used to illustrate the impact of trade and domestic policy changes on trade, and more recently few of them emphasise trade-environment interactions.

Recent literature on applied multi-region PE trade models which mainly focus on agricultural sector does provide very limited information on empirical works that evaluate agricultural trade-environment interactions. Among the PE trade models, AGLINK and MTM models of OECD, (OECD, 1991a,b,c; 1992), Commodity Trade Model of FAO, (FAO, 1986), GOL and SWOPSIM models of USDA/ERS, (Roningen and Karen, 1985; Roningen, 1986 and Roningen et al, 1991), CER and VOMM models of WB, (Ingco, 1987; Larson, 1990), FAPRI model of FAPRI-CARD, (FAPRI, 1989a,b), WTM model of SEAP, (SEAP, 1992), SPEL model of Bonn University, (Henrichsmeyer, 1990), IIASA-BLS model of Parikh et al. (1988), GLS model of Tyers and Anderson (1986), Tyers (1985), Zietz and Valdes (1990) and UNCTAD (1990) are the world wide used multi-country multi-commodity models which have highly disaggregated agricultural sector focus. New Zealand is included in AGLINK, MTM, FAO, GLS, Tyers (1985) and SWOPSIM explicitly, but, neither of them covers the agricultural trade-environment interaction. While GLS, Tyers (1985) and SWOPSIM models allow for calculation of the welfare effects of policies, these welfare effects do not include environmental externalities (Meilke, 1996) and they do not account for the social welfare changes of policies, (Anderson, 1992). A more recent version of OECD's AGLINK model has been designed to evaluate the market and trade impacts of environmental (reducing greenhouse gas emissions from agriculture), and trade and domestic policy changes (taxes, subsidies and regulations). However, the quantitative outcomes of this work has not been published yet. Another recent multi-country PE work that emphasise the effects of photosanitary measures on trade has been built by USDA/ERS. This model on the other hand excludes New Zealand and focuses on a single agricultural commodity.

One of the earliest environment focused PE models with an agricultural sector emphasis is Abler and Shortle (1992). In their work, effects on output quantities, prices, and land rents of changing chemical use is searched in a highly aggregated regional classification and on five agricultural products. New Zealand however, in this model is included implicitly. Anderson (1992), analyses the impacts of changing trade policies on the environment in the world's highly distorted markets of coal and food. While the countries are aggregated into three regions in the coal market, more disaggregated regional structure is used for food market in which New Zealand is included as a joint market with Australia. The model searches the effects of changing coal prices on global carbon and sulphur emissions through the change in production, and of changing food prices on chemical use in production. Kane et al. (1991) and Reilly et al. (1993), in their early works, evaluate the economic effects of climate change through changes in crop productivity by using SWOPSIM modeling framework. In Gunter (1996), a PE framework is used to analyse the effects of input subsidies or supply shifts (as components of environmental regulations) on production, returns to input, consumption, trade. While factor markets are explicitly incorporated to the model, there are only three regions (New Zealand is excluded), and the model focuses on wheat. Recently, Tsigas et al. (1997) analysed the effects of climate change by providing both PE and GE solutions. On the PE side, they evaluate the impacts of productivity shocks on crop growth via the changing effects of carbon emissions with a highly disaggregated primary and processed agricultural product coverage. However, this model also includes New Zealand implicitly. More recently Markandya et al. (1999) analysed the environmental impacts, in terms of soil fertility, water pollution, biological resources and health hazards, of growing different horticultural crops with a PE framework. They also examine the land shares of various products altered via the changing costs arose either by internalising environmental costs or giving different preferential access to certain products. In this model New Zealand is not included and regions are highly aggregated.

Recent literature, provides more information on multi-country CGE models that emphasise trade-environment interactions compared to PE ones. Apart from the differences that these models have in terms of their technical and covered economic aspects, the main trade-environment focus of these modeling works can be classified under three groups. The first group of works are the ones searching for the impacts of trade liberalisation and/or globalization on various environmental pollution levels, (Anderson and McKibbin, 1997; Ferrantino, 1999; Lejour, 1999; Rae, 1999; Strutt and Anderson, 1999; Tsigas et al., 1997), and welfare and growth (Babiker et al., 1997). The second group analyses the effects of changing input usage and/or technology and output demand on emissions, and also seeks the effects of emission taxes or abatement expenditures on the level of pollution, (Beghin et al., 1996) and changing international production and trade patterns (Babiker et al., 1997; Babiker and Rutherford, 1998; Piggott et al., 1992). The third group of models analyse particularly economy-wide costs and welfare effects of carbon restrictions, (Martins et al., 1993; Rutherford, 1993; Whalley and Wigle, 1993; Vouyoukas, 1993;).

In the first group of models, Ferrantino (1999), Rae (1999) and Tsigas et al. (1997) are more agriculture focused with respect to their sectoral disaggregation. While milk and meat are included separately with other aggregated industries in the first one, Rae (1999) includes 21 agricultural commodities/commodity groups and Tsigas et al. (1997) covers 5 agricultural sub-sectors. Only in Rae (1999) New Zealand is included explicitly. In the second group of models, Beghin et al. (1996) has the broadest environmental issue coverage with respect to emission types included in the model. However, the models in this group cover agriculture at aggregate level and New Zealand is only explicit in Babiker's both works. The last group of models, in general, interpret the outcomes in terms of overall economy and the industries are included at aggregate level. New Zealand is included implicitly in all the models analysing effects of carbon restrictions.

These models, however, by their nature are broad in coverage and more appropriate for modelling large scale effects rather than specific commodities, production practice and environmental interactions.

Of the types of trade models outlined above the global trade models (GTMs), due to their behavioural equations and structural characteristics, was chosen to analyse the multilateral policy effects and for reflecting both market and intervention failures that cause the interaction between trade and environmental issues. In particular a partial equilibrium framework was selected. The research used as its base for construction the VORSIM shell a GTM developed to simulate trade liberalisation policies which through its design made it possible to adapt to incorporate production and environmental effects. VORSIM has the further advantage of being based in Microsoft Excel rather than specialist software enabling it to be accessible to policy makers[3].

PE models select sectors and commodities of an economy as opposed to General equilibrium modelling. The advantage of PE modelling is it transparency, ease of simulation and, more importantly for the current study, the ease which production and environmental linkages can be included in the model.

A PE model can be multi-sector and commodity and is basically a series of supply and demand functions for each of these commodities and countries. Equilibrium is therefore where domestic demand and supply interact in autarky and for free trade where the price is equalised between countries.

This is illustrated in figure 1 which show two countries, NZ and the EU, and for one commodity for example butter. In autarky the equilibrium is at Pnz and Qnz in NZ and

[3] Regference to eth VORSIM shell can be found via the website http://members.aol.com/vorecon/vorsim.html

at Peu and Qeu in the EU. With free trade, equilibrium is at Pe where exports from NZ to the EU are AB which equal the imports into the EU at CD.

Through a partial equilibrium framework the impact of trade on the environment is simulated through relative social cost and benefit functions. Whether trade is a good or bad thing for the environment in this case depends upon the relative size of the externality in the importing and exporting countries plus the impact of the change in policy being simulated.

The most common is to compare the environmental consequences of no trade with free trade. In this case if the exporting country has the relative higher negative environmental effect then free trade will reduce environmental quality and vice versa if the importing country has the relatively higher negative environmental effect. This implies a divergence of the MSC and MPC in exporting country.

However as stated above free trade does not exist so rarely are we comparing no trade with free trade but more subtle changes in trade policy. Thus requiring careful modelling of not just trade policy but also the environmental effects.

A further problem is how to measure the difference between MSC and MPC. This in theory can be done by using non-market evaluation techniques. However, these are very costly to implement and do not have the degree of accuracy to calculate the social costs of different environmental negatives especially as affect the agricultural sector.

To overcome this problem environmental effects are not quantified in terms of social cost but in their physical units. This has the advantage that the effects of trade on different environmental criteria can be examined. It also allows the effect of environmental policy on trade, which most frequently implies constraints on physical variable, to be modelled. It does have the disadvantage however of not accounting for the economic cost of the environmental variables although this can be incorporated if such data is available.

3. The Empirical Model

The model was developed using dairy products as a test case. Dairy products are one of New Zealand's largest exports which have suffered perhaps the most from trade barriers and subsidised competition from other producers.

Moreover there are a number of concerns re the impact of dairying on the environment. There are concerns about slurry biohazards. Livestock can also increase turbidity in watercourses through trampling of stream and river edges. However, of particular concern is the effect on nitrate concentrations in groundwater. High milk yields per cow are achieved through a combination of cattle breed and their feeding regime. Grassland productivity can be raised by increased nitrogen fertiliser applications. This has a direct leaching effect in that not all of the fertiliser may be utilised by the grass. It also has an indirect effect in that a proportion of the nitrogen content of the grass (whether grazed or fed as hay or silage) is excreted by the cow and returned to the field. Similarly, cattle may be fed concentrates. The higher the desired the milk yield, the higher the grazing/fodder/concentrate input. The actual nitrate concentration in groundwater arising form a particular dairy system will depend not only on the management practices (e.g. N applications, stocking rates etc) but also upon environmental conditions. Crudely, if there is a lot of water to dilute the pollution it will cause less damage. Nitrates have been selected here as the environmental ‘damage’ to focus upon since they are the subject of policy measures in various countries, most notably within the European Union (EU) and the USA. Appendix 3 reports the physical technical data upon which the model was calibrated.

Lincoln trade and environment model

Building upon the trade flow relationships within SWOPSIM, the VORSIM shell was used to create a new model ‘PEAT’ (Partial-equilibrium Environment and Agricultural Trade). The original configuration has been extended to encompass sub-regions within the key dairy trading blocs plus explicit linkages between trade flows production method and the environment.

The trade flow relationships are based on a set of supply and demand equations of the general form:

$$q_i = c_i + \prod p_j^{\varepsilon ij}$$

where q_i is the domestic quantity supplied (demanded) of the i^{th} commodity, c_i is a constant term, p_j is the price of the jth commodity and $_{ij}$ is the cross-price (own-price when I=j) elasticity of supply (demand) between the i^{th} and j^{th} commodities. Excess domestic supply or demand spills over onto the world market to determine world prices. Domestic prices are based on world prices, plus any distortions caused by tariffs or other policy measures. For further details, see Appendix 1 and Roningen et al. (1991).

The $_{ij}$ parameters are key values in the model since they determine the responsiveness of domestic supply and demand to changing prices and policy measures. As currently configured, PEAT addresses 17 countries with five dairy trading blocs, the EU, New Zealand, Australia and the US, broken down into three supply regions. The model is actually calibrated for 14 commodities however only dairy products are modelled for production system and environmental effect across (see appendix). This results in a relatively large set of supply and demand equations embodying many parameter values The sub-national parameter values have proven somewhat elusive since regional supply data and studies appear to be scarce. Indeed, as Hansen and Heckman (1996; p94) note, “…it is surprising how sparse (and sometimes contradictory) the literature is on some key elasticity values”.

The price traded in the model for each region is a function of the world price and the exchange rate. The producer price in turn a function of the traded price and policies such as producer subsidies, separated into market support, direct, input, fees/levies and other. The producer price for raw milk is a function of the relative prices of the four types of dairy products marketed that is butter, cheese, skim milk, whole milk and liquid milk (the later of which is not traded in the model), as well as polices. This allows the policies affecting producer prices in dairy to be modelled at the product level or at the farm gate or raw milk price as appropriate.

Consumer prices are similarly a function of the relative prices of dairy products and any relative policies such as consumer subsidies.

The quantity produced of raw milk is broken down into three regions in the US, EU, Australia and New Zealand. Production is a function of the producer price of raw milk the prices of substitute/ complement commodities and purchase prices of inputs. The total raw milk supply is then obtained by adding the production from the three regions together. The model does have the capability of simulating maximum and minimum constraints to reflect polices such as production quotas and thus EU production was constrained by the internal production quota when current policies simulated. The quantity produced of dairy products is then a function of the production of raw milk and the relative prices of dairy products.

The consumption of dairy products in turn is a function of their prices and the income per head as well as policy variables.

To simulate the impact of changing market conditions on production and thus the environment the factors affecting nitrogen use and concentrate use have been modelled separately. The quantity fed of each type of feed grain is determined as a function of the relative prices of feed grains the price of nitrogen and the level of production of animal products including dairy. The total amount of concentrate fed to the dairy herd is then simulated as a function of the quantity fed of feed grain by type multiplied by the level of production.

The trade flow component of PEAT estimates domestic (regional) supply levels. These values are then converted into regional resource usage estimates through conditional input demand equations. Specifically, the usage of nitrogen fertiliser is estimated using Cobb-Douglas input demand equations of the form:

$$N/ha = q_{rm/ha\ b1}(P_c/P_N)^{b2}$$

Where N is the usage of nitrogen per hectare, q_{rm} is the regional quantity of raw milk produced per hectare (determined by the trade flow equations or a binding policy output quota), P_c and P_N are the input prices, and $_{b1}$ and $_{b2}$ describe substitution possibilities between the inputs (Varian, 1993).

Alternative input demand specifications were considered, including more flexible forms such as the Translog and less flexible forms such as the Leontief. To a large extent, the choice is somewhat arbitrary but a Cobb-Douglas specification was adopted since it permits input substitution without entailing additional complexity. This latter point is surprisingly important since significant difficulties arise when attempting to parameterise sub-national production relationships.

One concern here is a potential tension between the implicit production relationships represented by the trade equation elasticities and the explicit production relationship represented by the input demand equations. Given that the choice of a Cobb-Douglas form is arbitrary, it is unlikely that neither this functional form nor its parameter values will (except by happy coincidence) match with the trade flow equations. Two defences may be invoked here. First, as long ago as 1958, Hothakker demonstrated that farm-level production relationships may aggregate into very different sector-level relationships whilst more recently Diewert (1981) and Hertel and Stiegent (1996) show that sector level elasticities need not resemble firm-level elasticities. Stoker (1993) offers an interesting review of aggregation issues in the presence of heterogeneity. Second, the problem is actually one of incomplete information in that whilst the outputs may be reported, the inputs have not been observed directly and have to be inferred from other, sometimes oblique sources (Jakeman et. al. 1993; Hetel & Heckamn, 1996). Although more sophisticated techniques such as maximum entropy estimation can be deployed to address such incomplete information problems (ref), as a first-step it seems reasonable to adopt a simple and transparent approach that can be readily adapted to available information sources. In this particular case, the Cobb-Douglas form was arrived at after discussion with agricultural and environmental scientists and parameter values for the different regions were derived from a number of disparate sources including regional production data, farm-accountancy data, experimental farm data, 'model' farms and (subjective) expert opinion.

The final component of PEAT is a groundwater nitrate concentration equation of the from shown below, (Whitehead 1995):

$$Gnc\ (g/m^3/yr) = b_1 + b_2\ N/ha + b_3\ C/ha - b_4\ Qmk/ha\ /\ W$$

Where :-
Gnc = Average groundwater nitrate concentration
N/ha = Nitrogen applied per hectare per year
C/ ha = Concentrate per hectare
Qmk/ha = Quantity milk produced in litres per hectare per year
W = annual average drainage per year mm per year

The values for the coefficients for this equation were obtained from soil scientists in New Zealand and the UK (Ledgard pers comm, Sheil R. pers comm and Bidwell, V. pers comm).

To summarise, PEAT has extended the capability of SWOPSIM to model international trade flows.[4] More importantly, the inclusion of the conditional input demand and groundwater equations allows changes in trade flows to be translated into changes in resource usage and environmental damage. The structure of PEAT not only allows exploration of trade policies such as tariffs and import quotas, but it also allows exploration of environmental policies such as limits on nitrate concentration or input usage which may curb production below that determined by the trade equation (in which case the world market conditions will alter). Model solutions are calculated

[4] An example of the equation set for NZ is given in appendix two.

by Excel's 'Solver' Add-In[5] adjusting world market prices to force the world market to clear (i.e. all domestic production has to be consumed or stored somewhere).

4. Results

The model was calibrated using 1997 as the base year and then simulates any impacts out to 2010. Clearly the model generates large amount of data and here in this paper this is summarised into the main countries/regions in the model Australia, the EU, Japan, the US and New Zealand and for the key variables of the production of raw milk, producer prices of raw milk, trade by dairy product, and the physical variables, (that is, concentrate use, nitrogen use and ground water nitrates).

The model was simulated with no policy change and the results of this compared with the simulated impact of EU Liberalisation and also OECD Liberalisation, for the end of the simulation period 2010. The results of these simulations are presented below.

The model predicted that EU liberalisation leads to a rise in the producer price of raw milk in all the main countries included here, with the exception of the EU, as illustrated in figure 2, compared to no policy change. The price was predicted to rise by 13 per cent in both Australia and the US, 3.5 per cent in Japan, but only very slightly in NZ. The price was predicted to fall by 20 per cent in the EU. These results are consistent with expectations, with the possible exception of the marginal change in NZ producer prices (this may reflect NZ preferential access into the EU under current policy). When the results of the simulation of OECD liberalisation are compared to the no change base solution, prices in the EU and Japan were predicted to fall by 9 and 8 per cent respectively and by just 2.5 per cent in the US. Not surprisingly the greatest predicted rise in prices were in Australia at 14 per cent and NZ at 13 per cent compared to no change.

The predicted impact of EU liberalisation on the production of raw milk was a fall in the EU of 7 per cent, with increases in production of 4 per cent in Australia, 5 per cent in the US, 3 per cent in Japan and little change in NZ production, as illustrated in figure 3. The predicted impact on milk production after the OECD is liberalised is a small increase, of 3 and 4 per cent respectively, in Australian and New Zealand production and a fall in production in the EU, Japan and the US, by 3, 8 and 2 per cent respectively.

The predicted impact of EU liberalisation on trade in dairy products is shown in figures 4 to 7. Figure 4 shows a predicted fall in the net exports of butter from the EU, by 350 thousand tonnes. US exports of butter increase by 26 per cent; Australian and New Zealand exports are predicted to rise by 7 and 3 per cent respectively and Japanese imports of butter are predicted to fall by 25 per cent.

The results of the simulation for OECD liberalisation predict EU exports of butter fall by 300 thousand tonnes, from the no change scenario, in 2010. US exports are predicted to fall by 53 per cent to 100,000 tonnes and Japanese imports are predicted

[5] This Add-in is also available for Lotus 123 and Quattro Pro spreadsheet packages and deploys a Generalized Reduced Gradient (GRG2) nonlinear optimization algorithim, see http://www.frontsys.com for further details.

to rise by 40 per cent. Australian exports are predicted to rise by a similar amount than under the EU liberalisation scenario but New Zealand exports are predicted to rise by 14 per cent.

The predicted change in the quantity of cheese traded by 2010, under the three policy scenarios, is illustrated in figure 5. As in the case of butter trade EU liberalisation affects NZ trade marginally with NZ benefiting the most by OECD liberalisation. Australia, on the other hand, gains the most when the EU is liberalised and less with OECD liberalisation, thus cheese exports rise by 27 per cent by 2010 with EU liberalisation compared to a 15 per cent rise when the OECD is liberalised.

EU imports of cheese are predicted increase by 236 per cent when the EU is liberalised, compared to a 50 per cent increased if the whole of the OECD liberalises. The US is predicted to become a net exporter of cheese when the EU liberalises but imports actually rise by 70 per cent with OECD liberalisation.

Trade in whole milk powder and skim milk powder are illustrated in figures 6 and 7. These reflect, not surprisingly, the patterns of trade under the scenarios for butter and cheese. NZ again gains more from full OECD than EU liberalisation.

To simulate the impact of liberalisation of the EU and OECD on the physical inputs and environmental variables the key countries/regions in the model were disaggregated into three sub regions by production system type. Raw milk production per sub region is shown in figure 8. The effect of the policy scenarios on nitrogen and concentrate use was simulated as well as the consequential effect on groundwater nitrates.

The simulated impact on Nitrogen use per hectare of the three policy scenarios is illustrated in figure 9. This shows that there was a predicted rise in Nitrogen use per hectare with the liberalisation of the EU compared to the no change scenario of, between 5 and 6 per cent in Australia, 1 and 4 per cent in NZ, and 7 per cent in the US, with nitrogen use per hectare falling by around 17 per cent in the EU.

The full liberalisation of the OECD led to a small increase in nitrogen use in Australia. In NZ there is a predicted rise in nitrogen use per hectare of 14 per cent in South Auckland, 10 per cent in the South Island and 12 per cent elsewhere, compared to the no change base scenario. OECD liberalisation led to predictions of more modest rises in nitrogen per hectare in the US of about 2 per cent and in the EU a fall of around 10 per cent is predicted, compared with no change in policy.

The simulated changes in concentrate use per cow are illustrated in figure 9 showing as a result of liberalisation of the EU a rise in concentrate use of 4 per cent in the US and Australia, and a fall of 3 per cent in NZ and a 22 per cent fall in the EU. OECD liberalisation leads to a predicted rise in concentrate use of 2 per cent in Australia, a fall of 7 and 18 per cent in the US and the EU.

The impact on ground water quality obviously reflects the changes above, as illustrated in figure 11. In New Zealand and Australia groundwater nitrates were predicted to alter marginally under both policy scenarios. Predicted changes in groundwater nitrates in the US ranged from a rise of between 2 and 4 per cent in the case of EU liberalisation and marginal changes with OECD liberalisation. Under both policy scenarios groundwater nitrates fell in the EU by between 3 and 8 percent when the EU was liberalised and between 3 and 4 per cent when the OECD was liberalised.

5. Conclusions

Formal agricultural economic analysis is credited with providing valuable and timely information for the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) which concluded in 1992 (Meilke et al., 1996). The raised profile of agriculture within the inaugural World trade Organisation (WTO) negotiations ensures that there will be a continued need for formal analysis. The challenge here is to shift attention from aggregate outcomes to address distributional issues, such as localised environmental impacts.

Further research involves sensitivity analysis of the coefficients in the model to assess their degree in importance. This will help to direct research effort into which values should be given priority for reestimation. The definition of regions needs to be refined and the basis of this definition determined. Ideally these should be on the marginal farming system which is most likely to change given policy impact. However that depends on firstly the availability of scientific data and secondly the ability for that region to be defined in terms of area and importance.

The model needs to be continued to be developed to reflect more closely trade polices in particular those which affect NZ such as preferential access into the EU and the impact of import quotas.

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Appendix 1: Countries and commodities in the model

AR	Argentina	
AU	Australia	Victoria
		NSW
		Other AU
CN	Canada	
CZ	Czech Republic	
EU	European Union (15)	West (UK, Ireland, Netherlands, Denmark)
		East (Germany, France)
		Other EU
HU	Hungary	
JP	Japan	
MX	Mexico	
NI	New Independent States	
NO	Norway	
NZ	New Zealand	South Auckland, Waikato
		South Island
		Rest of NZ
PO	Poland	
SL	Slovakia	
SW	Switzerland	
TU	Turkey	
US	United States	California
		Wisconsin, Michigan, Minnesota, Pennsylvania, New York
		Other US
RW	Rest of World	

Commodities

WH	Wheat
CG	Coarse grains
SU	Sugar (refined)
OS	Oilseeds
OM	Oilseed meals
OL	Oils
BV	Beef, veal
PG	Pig meat
SH	Sheep meat
WL	Wool
PY	Poultry meat
EG	Eggs
MK	Raw milk
ML	Milk (liquid, other products)
BT	Butter
CH	Cheese
MW	Whole milk powder
MS	Skim milk powder

Appendix 2: Sample Model equations for NZ

NZqpMKA = 0.784775*NZfpMKA*NZppBV^.08*NZppMK^.8*NZpcWH^.04*NZpcCG^-.4*NZpcOS^-.01*NZpcOM^-.09*(1+.02*WDt)

NZqpMK = 0+NZqpMKA+NZqpMKB+NZqpMKC

NZqpBT = 0.01007075*NZfpBT* NZqpMK* NZppML^0.01* NZppBT^0.15* NZppMS^0.1* NZppMK^-0.13

NZqcBT = 0.4627113*NZfcBT*NZpcOL^.04*NZpcBT^.45*NZpcCH^.01*(NZgdp/NZpop) ^.19*NZpop

NZqtBT = 0+0+NZqpBT-NZqcBT-(NZqeBT-NZqe:1BT)

Nzrva = 0+.05*NZpcWH+.84*NZpcCG+.01*NZpcOS+.1*NZpcOM

NZewMKA = 0*(.62*NZqfWH+.66*NZqfCG+.59*NZqfOS+.59*NZqfOM)*NZqpMKA

NZexMKA = 3636.9*((NZrva/NZrvb)^0.91)*NZqpMKA

NZezMKA = 30.8+.028*NZexMKA+.0018*NZewMKA.00065* NZqpMKA)/ NZeyMKA)

Where:

NZ	New Zealand
WD	world
ew	concentrates (t/cow/yr)
ex	fertilizer nitrogen (kgN/ha/year)
ey	average annual drainage (mm/year)
ez	groundwater nitrate levels (mg/litre)
fc	shift in consumption
fp	shift in production
gdp	gross domestic product index (1979=100)
pc	consumer price ($/t)
pp	producer price ($/t)
pop	population (000)
qc	quantity food and other consumption (000 t)
qe	quantity ending stocks (000 t)
qf	quantity fed (000 t)
qp	quantity production (000 t)
qt	quantity net trade (000 t)
rva	concentrate fed (WH, CG, OM, OS) price ($/t)
rvb	nitrogen price ($/t)
t	time
BT	butter
BV	beef, veal
CG	coarse grains
CH	cheese
MK	raw milk
MKA	milk, region A; MKB milk, region B; MKC milk, region C
ML	milk (liquid, other products)
MS	skim milk powder
OL	oils
OM	oilseed meals
OS	oilseeds
WH	wheat

Appendix 3: Technical data

Region	Production Per cow litres	Average Stock Rate/ha	milk output litres	Area 000ha	Concent rates Kg/cow /yr	Fertiliser N/ha	fertiliser price nc /kgN	Average Drainage Mm/yr
UK	5,123	2.1	14639000	1360.71				
Netherlands	6,065	2.7	11013000	672.529				
Ireland	3,932	1.6	5430000	863.110				
Denmark	5,620	3.0	4695000	278.469				
France	4,729	1.5	25083000	3536.05				
Germany	4,636	2.0	28776000	3103.53				
Belgium	4,434	2.4	3416000	321.004				
Italy	4,224	2.4	10690000	1054.49				
Luxembourg	4,692	1.9	267000	29.9502				
Greece	3,595	1	755000	210.014				
Spain	4,754	1.5	6038000	846.726				
Port	4,863	1.5	1763000	241.689				
Austria	4,296	2.4	3034000	294.266				
Finland	6,147	2.7	2431000	146.473				
Sweden	7,012	3	3316000	157.634				
West EU				3174.83	2100	350	0.4	400
East EU				6639.59	1000	125		200
Other EU				3302.24	2100	250		300
Australia:	4,682							
Victoria	4715	1.0	5978000	1267.87	500	200	0.53	300
NSW	4,972	0.5	1253000	504.022	1000	150		300
Rest of Australia	4,608	0.5	2410000	1046.01	860	100		200
USA:	7,238							
California	8,439	10	12590000	149.188	5500	0	0.31	200
WI, MI, MN, PA, NY	7,182	3	26959000	1251.23	2900	300		500
Rest of USA	6,770	2.7	31583000	1727.83	2000	150		300
New Zealand								
Auckland	3278	2.8	4540000	494.639	0	95	0.7	700
South Island	3874	2.6	2768000	274.810	18	201		350
rest of NZ	3300	2	3765000	570.454	10	150		400

Figure 1: Partial Equilibrium Model

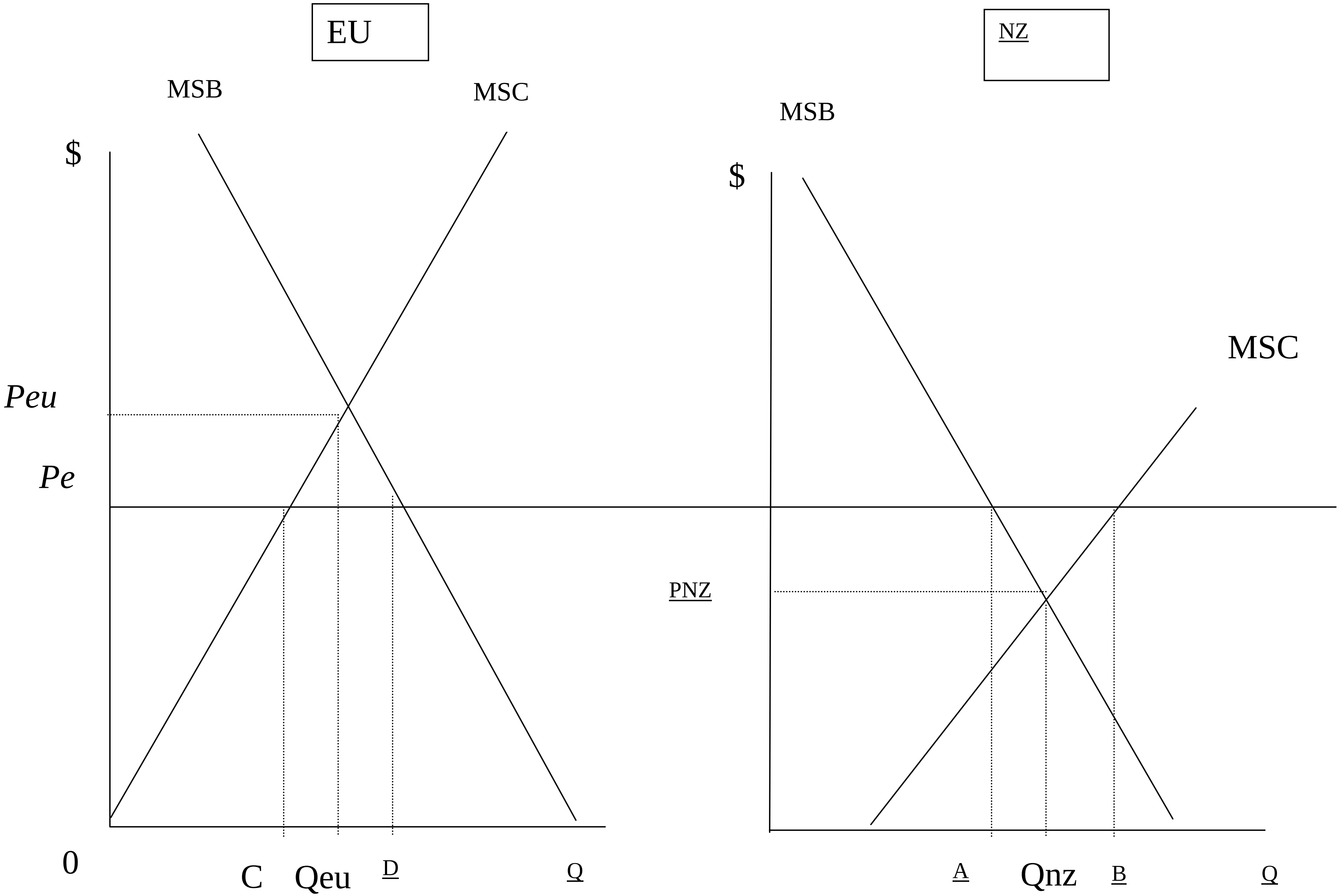

Figure 2: Producer price of raw milk 2010

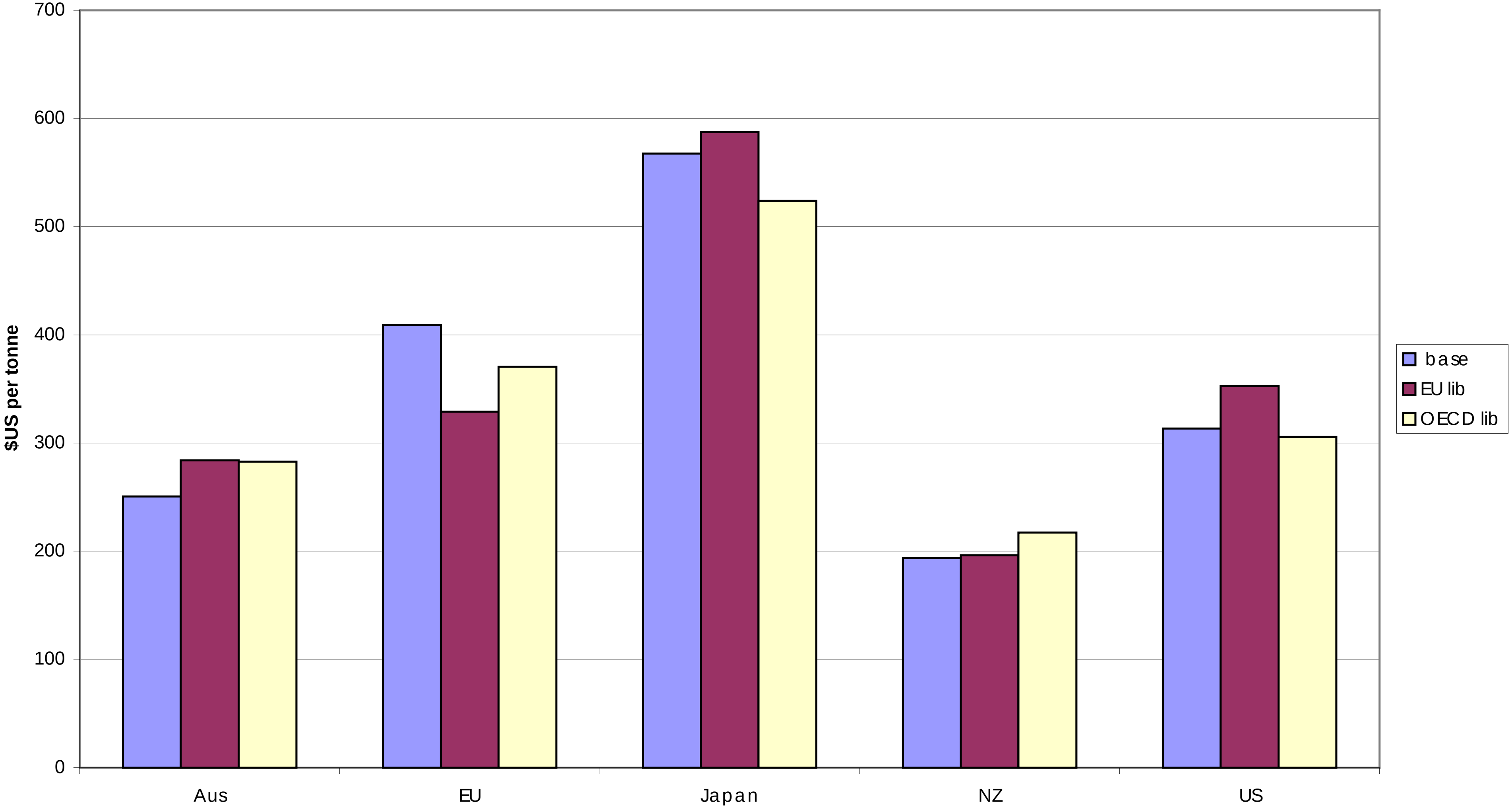

Figure 3: Raw milk production by selected countries 2010

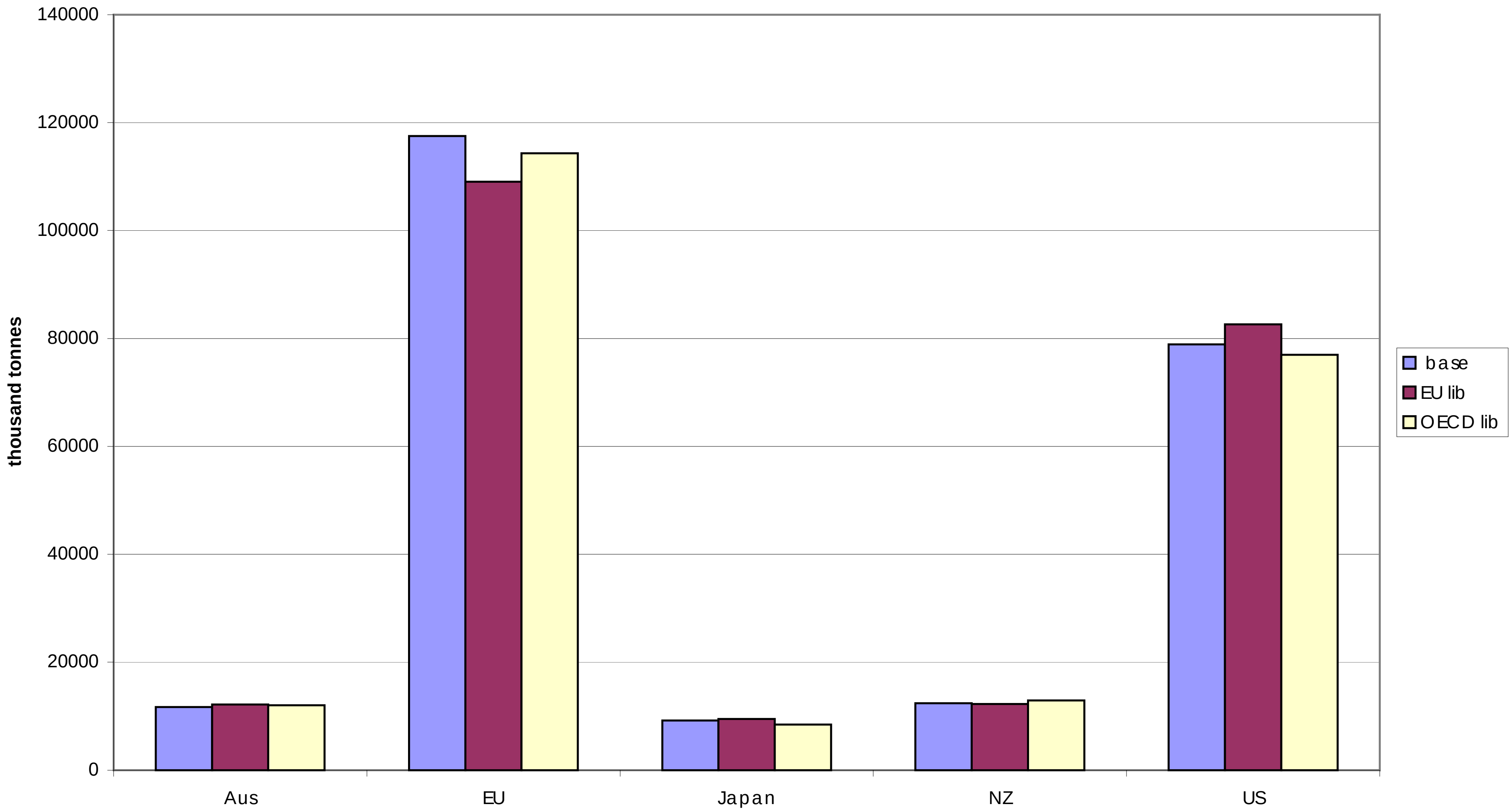

Figure 4: Quantity traded of butter 2010

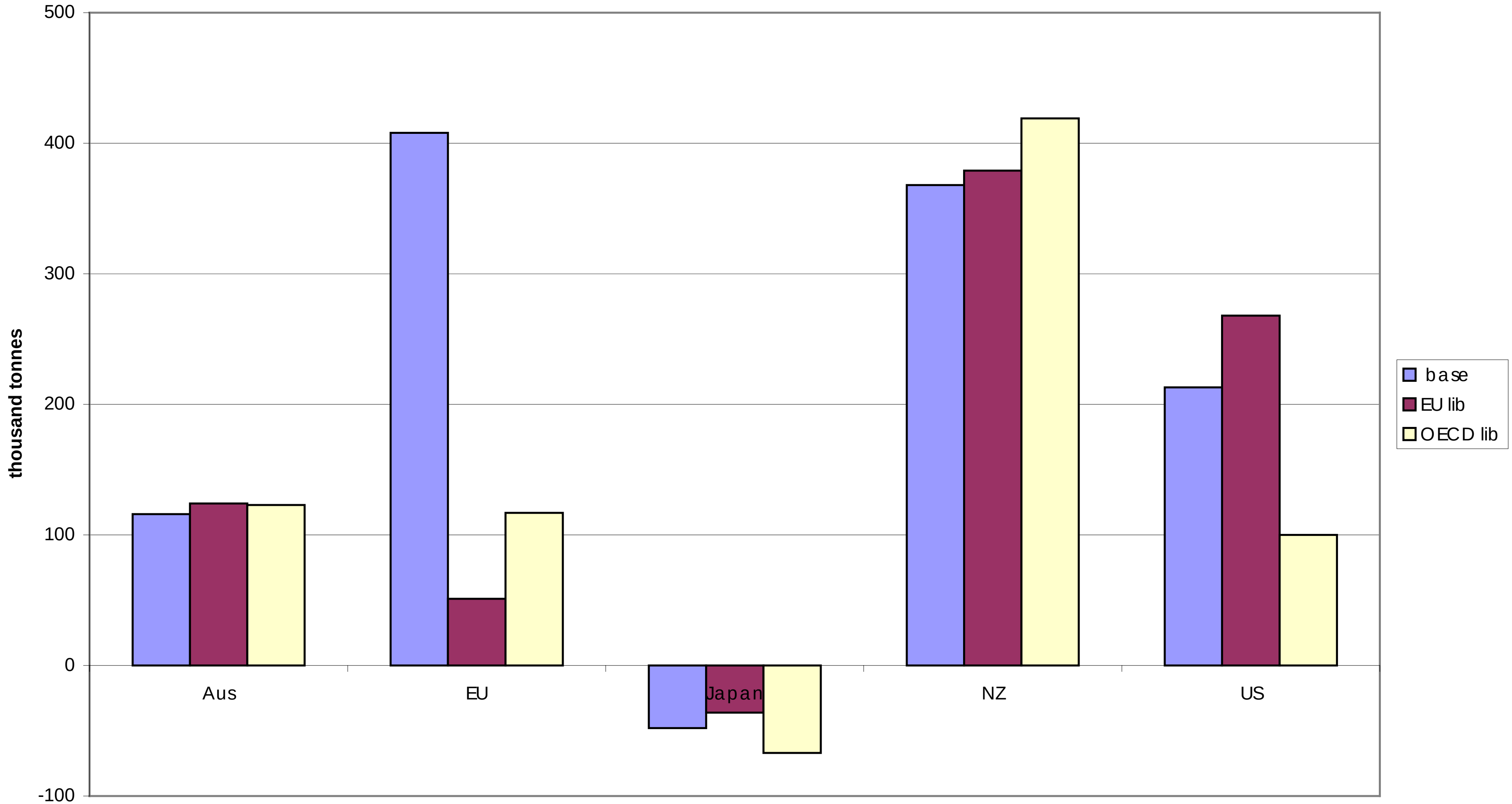

Figure 5: Quantity traded of cheese 2010

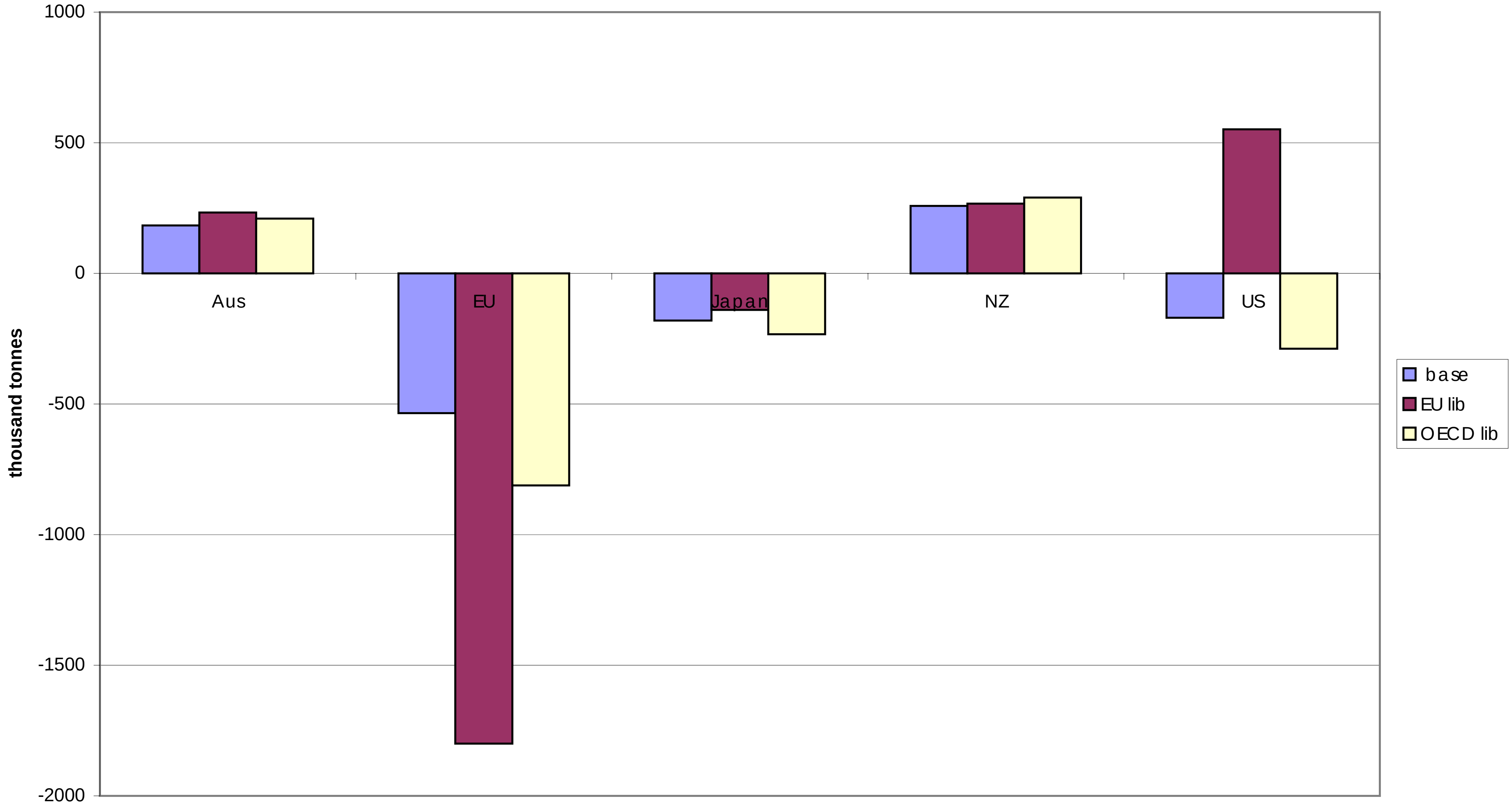

Figure 6: Quantity Traded of whole milk powder 2010

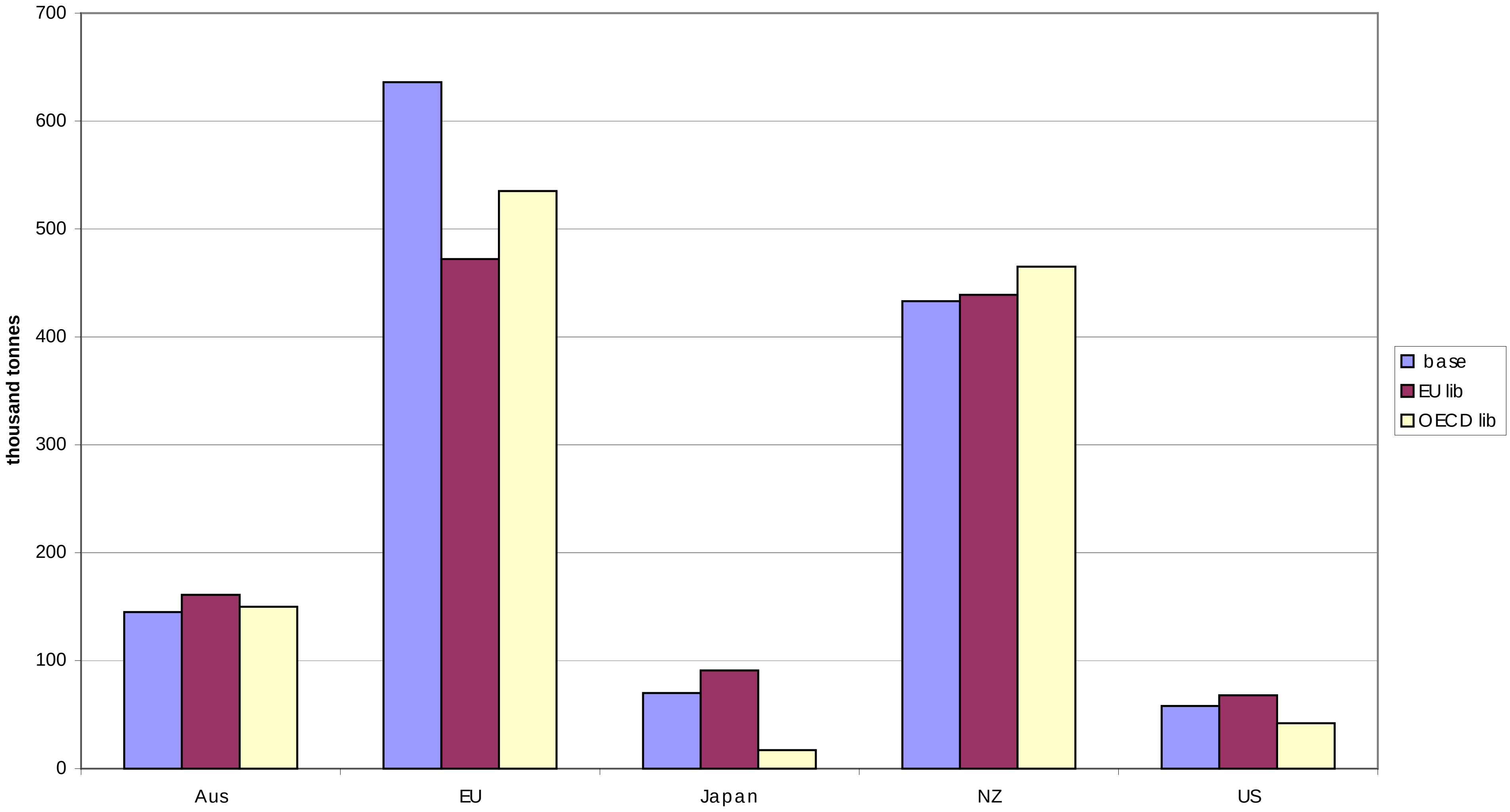

Figure 7: Quantity traded of skim milk powder 2010

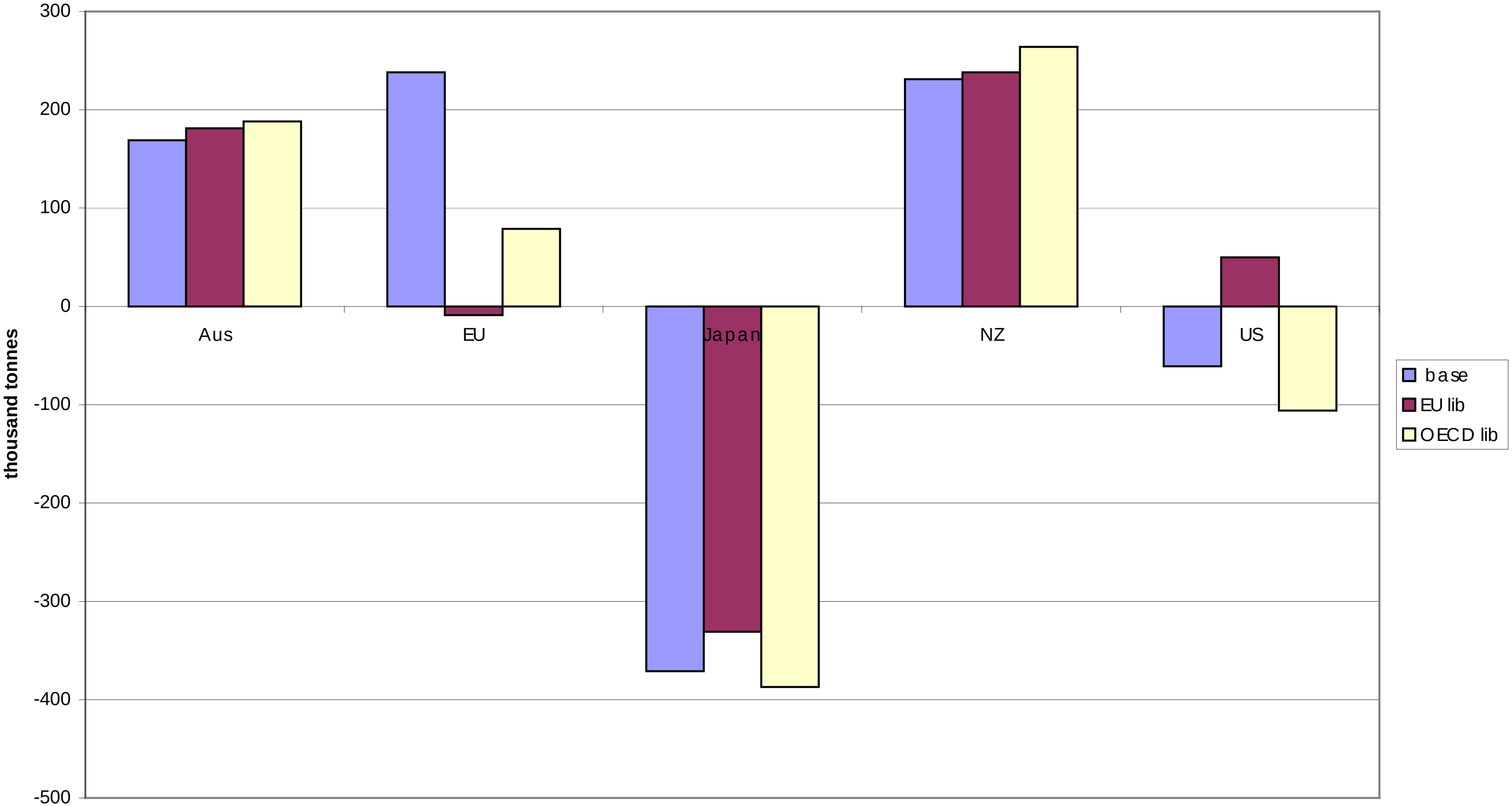

Figure 8: Raw milk production by region 2010

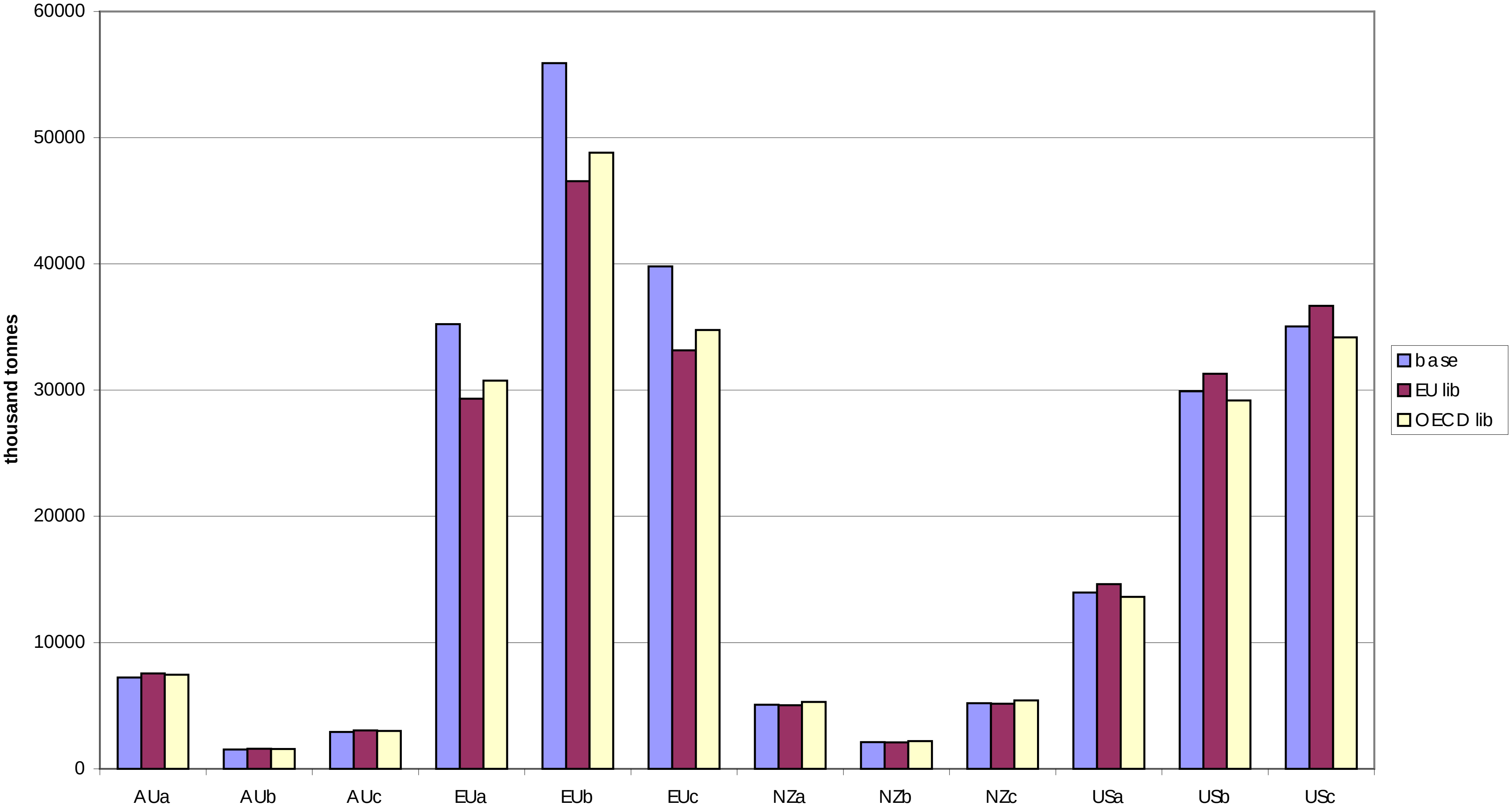

Figure9: Nitrogen use kilogram per hectare by region 2010

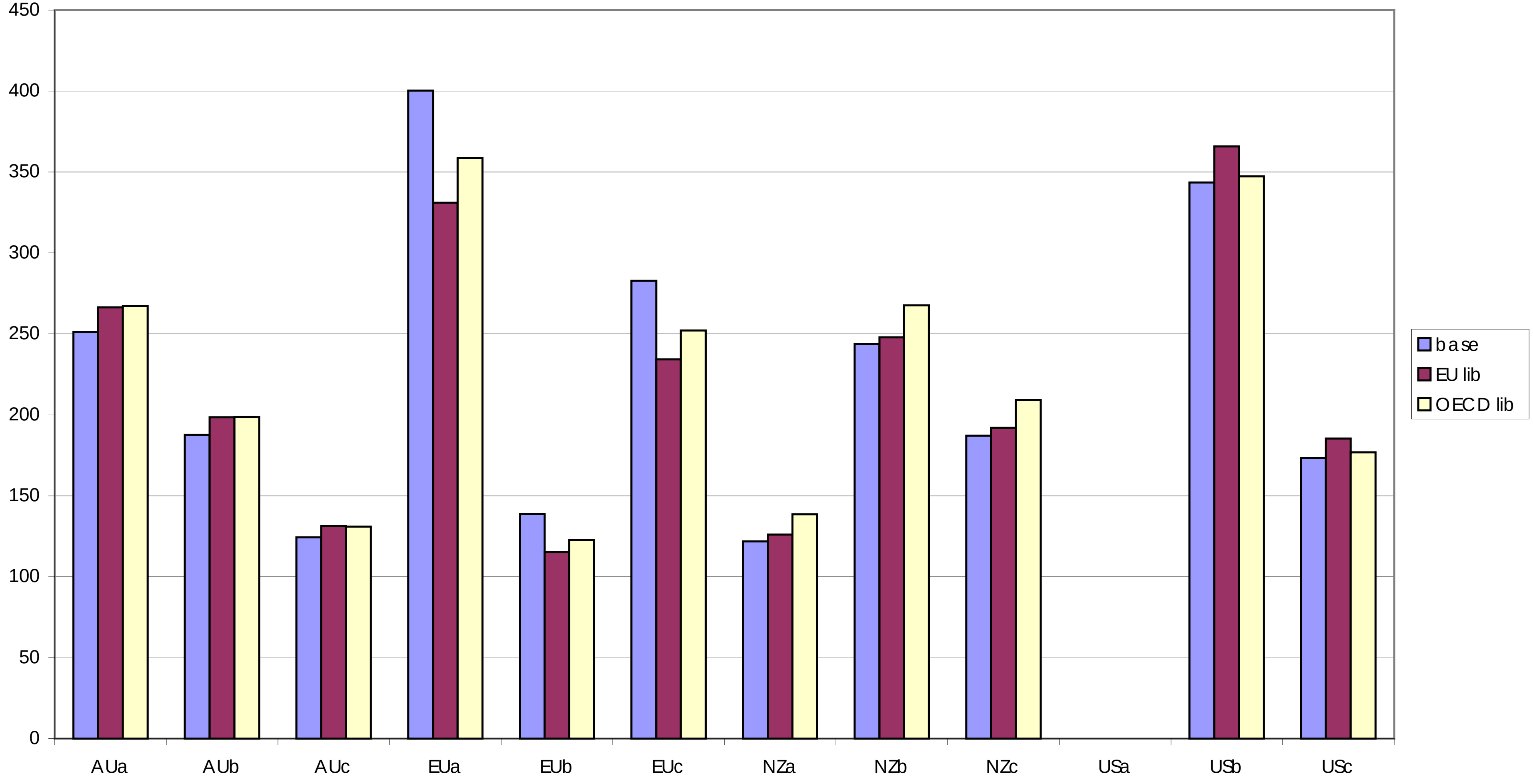

Figure 10: Concentrates tonnes per cow per year 2010

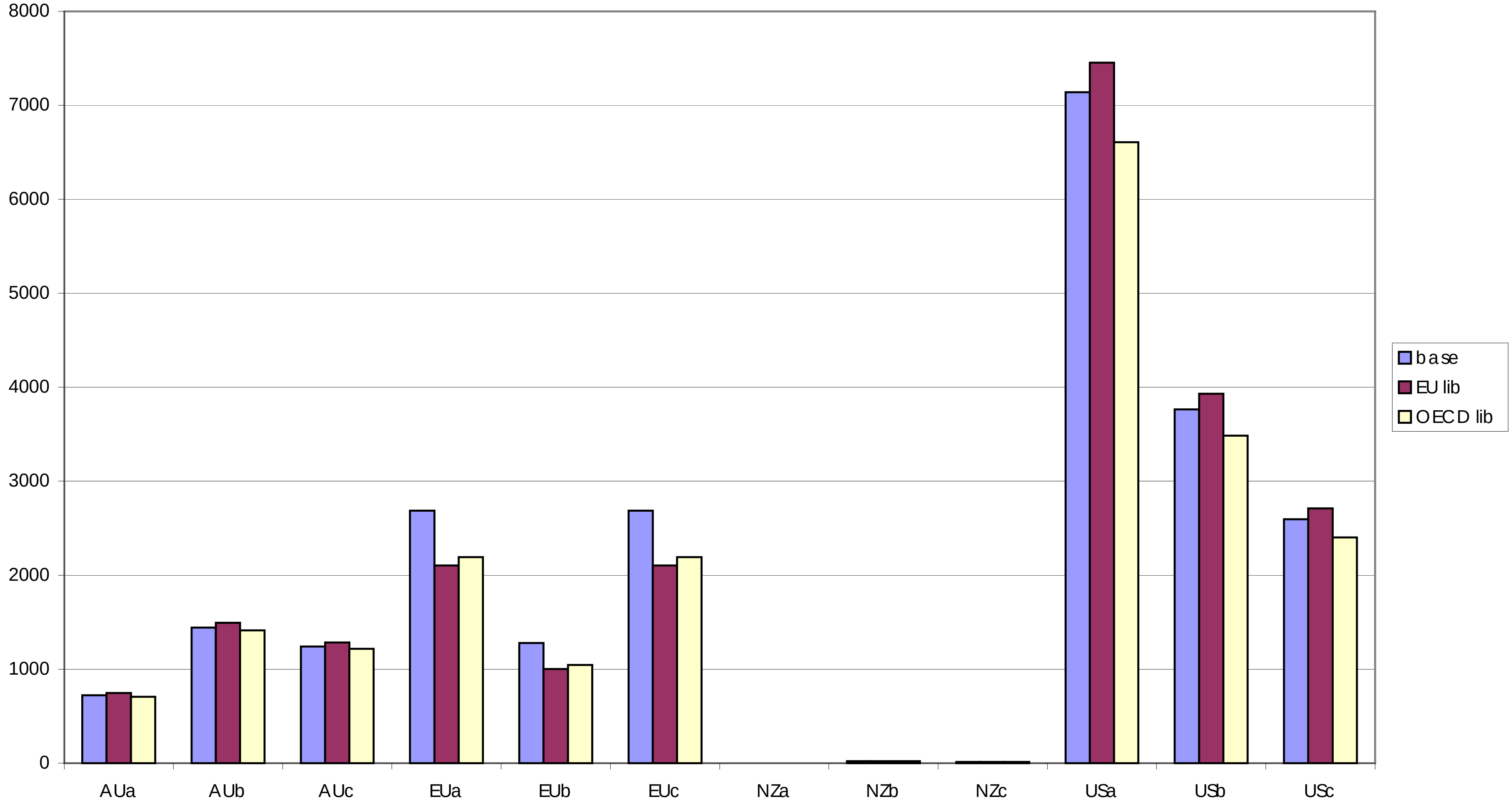

Figure 11: Groundwater nitrates by region 2010