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Portfolio Stress Testing

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The Basel II accord will have profound and far reaching effects on the global banking system. It sets in place a series of guidelines against which banks should manage their portfolios to ensure that adequate capital reserves are maintained. The idea is that institutions holding riskier portfolios should keep higher reserves on hand than those with relatively safe investments. Previous banking regulation took more of a one-size-fits-most approach to banking, meaning that reserves were often unnecessarily high for risk-averse entities and dangerously low for the few banking mavericks that are perpetually in our midst. With mandated risk management processes in place under Basel II, widespread bank failures are anticipated to be a thing of the past.

Credit modelers tend to view business cycle fluctuations as second order issues; the prevailing view is that such information provides little value added to the risk assessment process when compared with sources of information drawn from individual account level data. In one way, the current models are right—knowing that your credit score is 700 and mine is 600 is much more informative of our relative default risk than the fact that you live in depressed Detroit while I live in manic Manhattan. A 700 at one point in the housing cycle, though, may bear little resemblance to a 700 at a different point. The current subprime mortgage problems should neatly illustrate that a shifting macroeconomic environment has the potential to affect everyone's probability of default by enough to send an entire industry to the brink of collapse, risking the expansion of both the U.S. and world economies. If a subprime mortgage lender had correctly factored likely future house-price growth paths into their models back in 2005 or early 2006, there is every chance that they could have staved off insolvency. Had every mortgage lender done so, something else altogether might be dominating the global financial media.

Since Basel II is designed to assist banks and lenders in avoiding insolvency when events like this unfold, the role of the business cycle in risk assessment should be considered absolutely central.

The purpose of this article is to explain, in some detail, an economist's view of Basel II implementation. In many respects, the current credit problems provide a useful framework for discussing the accord since we can consider, for example, steps that failed banks might have taken to maintain solvency in light of recent events. Additionally of interest are factors that surviving lenders might consider in their risk management practices going forward. What happens, after all, if conditions in the sector deteriorate to an even greater extent than seems likely now? In addressing these issues, we will highlight Moody's Economy.com's views of Basel II from an operational perspective. Our approach to capital adequacy assessment and stress test design will be discussed; these are the primary areas where economists can and should become actively involved with respect to the Basel II accord.

In this article we will focus on retail credit risk. With some modification, however, many of the ideas discussed here are equally applicable to corporate or even sovereign risk if it is observed at a subnational level. We will focus on the U.S. given that the best current example of a stressed industry happens to reside in that country. Naturally, though, these ideas can be modified to suit local conditions observed in other countries as well.

Pillar I

The Basel II accord is typically split into three pillars, which aids in the discussion of the document. The first pillar concerns the calculation of minimum capital reserve requirements to cover the various quantifiable risks faced by a bank or similar institution. The risks are split into credit risk, the risk of nonpayment of outstanding debts owed to the institution; operational risk, ostensibly the risk of a failure of management practices; and market risk, the risk that market fluctuations, like a stock market crash or currency appreciation, will impact on the solvency of the institution in question. Economists have a clear role to play in assessing all three of these exposures. For example, an economist's view of likely future interest rate moves is directly relevant to the question of market risk exposure. Similarly, economists spend considerable time examining agency problems—ways to ensure that managers act in the best, long-term interests of the principal, the share holders or owners of the company that employs the economist. These types of considerations are directly

related to the assessment of operational risk management practices.

Our focus here though is on credit risk. The most enticing aspect of Pillar I is that it allows banks to establish an internal ratings-based approach to the assessment of such risk. The idea is that banks can adopt their own methodologies, following a number of rigorous guidelines, to assess their own capital adequacy requirements. Alternatively, banks can resort to standardized approaches but these will not yield any competitive market advantages. This means that, under Pillar I, bigger banks will probably elect to construct, update and validate state-of-the-art credit risk models in order to attain Basel II compliance.

Traditionally, business cycle fluctuations and macroeconomic information have been afforded only second order importance in the construction of these models. For example, if one is preparing a mortgage probability-of-default (PD) model to predict likely future performance and the future path of house prices is not a key driver, the model is dangerously misspecified. If I was to buy a house with 100% loan-to-value at the end of a long housing boom, any decline in price will see me enter negative equity territory. This situation is foreseeable for the lender and its incidence clearly affects not only loss given default but also the probability of default as well. The incentive for the borrower to remain current on a loan tied to a worthless asset is rather slimmer than if there was significant amounts of equity to defend. If the same loan was written under "normal" circumstances where markets were growing steadily, the probability that the loan would ever be in negative equity would be very low indeed.

The simple fact, as has become obvious in the current subprime mess, is that falling prices can dramatically affect individual credit outcomes. Similarly, though unemployment has been relatively stable of late, a potentially looming bout of elevated joblessness would have a similar impact on default statistics. Traditional credit risk models, which are based on individual loan level data and focus on predicting account specific outcomes, are, given high-quality data, great at determining whether one person is more likely to default than another. They are not so good at determining the likelihood that either or both will default because of detrimental circumstances that are external to both parties.

Folding aggregate information, like unemployment or house prices, into individual level credit risk models is, however, a vexed issue. If you were some kind of deity and could build a dream data set, you would include things like the actual employment status of each individual, the future probability of the individual being unemployed and the prevailing market house price of the individual's home during each relevant time period. Such fantasy data do not exist; in the real world, aggregate information and macroeconomic forecasts must be used instead. Many of these aggregates are available at the zip code level in the U.S. but even this is a long way from the individual level data that are truly needed to model these relationships at the account level.

The problems with using aggregates to model individual behavior are twofold. First, academic research has demonstrated that including aggregate data in individual regressions leads to biased and inconsistent estimates of the impact of the macro factors. Second, if you imagine the amount of variation in origination credit scores contained in a portfolio of 100,000 credit card accounts and compare this to the amount of time series variation in the U.S. unemployment rate it will be obvious which factor will have the higher explanatory power in a PD regression model. Further, the credit score variable serves as a proxy, in large part, for unemployment since those with lower credit scores are presumably more likely to become and remain unemployed in the event of an economic downturn. The measured impact of a change in the unemployment rate is therefore swamped by the variation present in the individual level data.

Suppose that a model with only individual credit score and aggregate unemployment is fit to individual level data. Now suppose that a recession is likely, so unemployment is predicted to rise substantially. For many individuals in the sample, this event will be a financial disaster, but for many, apart from increased anxiety, there will be no major impact. To fully reflect the impact of higher unemployment on the individual probability of default you need to find a way to share out the pain of higher unemployment in a way that reflects true individual future probability of unemployment based on individual level information like the credit score. Just sticking macro factors in PD models is the wrong approach to modeling and forecasting their likely future impact.

To get around these types of problems, if Moody's Economy.com was overseeing the building of a Basel II PD model, we would start out by modeling the future path of aggregate default statistics by tying them to macroeconomic and portfolio level information of a matching level of aggregation. The future path of these aggregates would then be determined using appropriate forecasts of the various inputs. Ideally, the modeling would be done at the highest possible level of disaggregation without breaching any of the other constraints. If relevant and reliable zip code level macro factors were available, for instance, this would be optimal. Alternatively, modeling could be done at the metro area or, if necessary, at the state or even the national level. Once the forecasted default rate, for, say, Boise, Idaho was determined, and once the standard PD model had been used to order all of the accounts held by residents of Boise in order of default likelihood, the relative individual default probabilities would be benchmarked to the previously described forecasted aggregates. This would ensure that the macro factors are fully reflected in the individual level data for defaults without altering the relative probability of default for each account in the sample. In our view, this is the best, if not the only practical way to account for external macro factors in the credit risk modeling framework.

The other point about standard parametric PD models is that the elasticities of various default factors to individual characteristics may be regionally heterogeneous and/or dependent upon business cycle

fluctuations. For example, suppose you construct an account level model of mortgage time-to-default and find, as you might expect, that credit score is positively associated with this variable. Further, assume that those with lower credit scores are more likely to become unemployed in the event of a recession and that unemployment boosts the probability of default, both of which seem like reasonable assumptions. Under these conditions, the elasticity of time-to-default to credit score will be higher under recessionary conditions than if the economy is booming and jobs are plentiful. A model that assumes constant elasticities or slopes across the business cycle is likely to incorrectly determine the probability of default for certain groups within the portfolio under changing economic conditions.

The key point to this discussion is that the economy is a key factor in determining retail credit risk outcomes and must be fully represented in all relevant models. Those using models that do not incorporate economic data, or that do not use macroeconomic information correctly, are not modeling credit risk properly. The estimated level of risk posed by individual account holders derived from methods that ignore the economy are likely to be too static under circumstances where the economic landscape is predicted to shift beneath borrowers' feet.

Stress testing

The specific role of economic analysis in the Basel II accord enters mainly in the guise of stress testing. Throughout the document, the importance of assessing the performance of the portfolio under stress is stressed. The stress testing protocol is required to be both "rigorous and comprehensive" and cover "hypothetical or historical scenarios that reflect worst-case losses" in both "public and private equities." The scope of the requirement for stress testing seems to be institution wide. Every aspect of a bank's operations and every risky position held by the bank must be stress tested for a comprehensive response to the Basel II document.

So what constitutes stress in the context of financial portfolios? To our way of thinking, stress can be found in three distinct guises. First, a portfolio of assets might be stressed as a result of bad management. The old saying that you cannot legislate against stupidity is relevant here, however. The Basel accords must implicitly assume, at some level, that participants' operations will be managed at least competently if not expertly. This seems like a banal observation but it does have a bearing on the stress testing process. If management actions can be appropriately incorporated into the models used to conduct the stress tests, exploring potential efforts at mitigation may allow the bank to reduce capital reserve requirements while remaining completely true to both the letter and spirit of the Basel II accord.

The other two sources of stress are rather more direct. If a stress faced by the portfolio is recognized, at least as a possibility, with some degree of foresight, this is a very different animal from those stresses that only become apparent with the benefit of 20-20 hindsight.

Imagine, for example, two similar hypothetical U.S. subprime mortgage lenders observed at the beginning of 2006. Assume that one bank's stress test involved an assumption that the housing market would become overbought, that lending standards would slip way too far, way too fast and that this would lead to a significant house-price bust. The other bank's stress test involved $150 per barrel oil by mid-2007 causing distress for borrowers but only a modest slowing in house-price growth and overall lending activity. At the time, you could have found someone to argue both sides of the debate as to which of these downside scenarios was the more likely. Subsequent events have shown, of course, that the first bank's stress test was far more prescient than that erroneously conducted by the second bank.

Presumably, the first bank would gain some benefit from having applied the "correct" stress test to the portfolio. If the utility derived from the stress test is viewed narrowly, as a tool for simply gaining a Basel checkmark, the prescience of the stress test may be irrelevant. It is entirely plausible, for example, that both stress tests described above would have earned the banks Basel II compliance. It is likely, however, that the first stress test, aimed more specifically at the particulars of the portfolio under consideration, would yield higher figures for the underlying capital reserve requirement. The first bank may thus be solvent today while the second may be one of the many lenders to have already failed in the face of massive subprime mortgage losses.

The other benefits of maximizing the prescience of the stress test are external to the Basel II checkmark acquisition imperative, at least in terms of credit risk assessment. If the Basel II compliance process is viewed more broadly by managers at the bank, and where the stress testing process is allowed to inform management operations, a high-quality stress test could effectively kill many birds with one stone. Even though it was only presented as a severe downside scenario, in the stated hypothetical example, the first bank may have paused to consider the ramifications of its actions during 2006 given the nature of the research that was then on the table. It is unrealistic that a gung-ho subprime lender in the midst of a mortgage frenzy would eschew significant amounts of market share simply because of the existence of a damning stress test. The existence of such a document, however, may well have taken the edge off the actions of the bank and kept it safe from insolvency now that the fragility of subprime mortgage portfolios is obvious to all.

The other apparent danger here comes from doing the stress test internally. Is it realistic to believe that a small subprime lender, in early 2006, would get its own research department to conduct a stress test and then have received the one used by the first bank in our hypothetical example? Designing stress tests like this requires objectivity and candor and a realization that the stress testing project may call into question aspects of the operations of the business more generally. We are, after all, posing questions that potentially involve the end of the company if they are not answered correctly.

In our view, a strong incentive exists to outsource the stress testing activities of a lender and that this incentive is negatively associated with the size of the institution's

portfolio. Further, we take a holistic view of the entire Basel II document, both in terms of mitigating and managing the excessive risks implied by stress testing and from the perspective of setting capital requirements correctly and to the lowest possible level without unduly raising the probability of future insolvency.

Of course, no one can predict future downside stressed scenarios with perfection. Some can predict these events more perfectly than others, though. Deep and current global macroeconomic analysis will be more likely to lead to accurate identification of potential future downside scenarios than will less deep and less current forms of economic analysis.

Naïve errors

There are some approaches to stress testing that can be easily rejected. One problematic approach involves taking a naïve, purely statistical or historical view of what constitutes stress. Suppose we model a portfolio and find that interest rates, inflation, economic growth and house prices are the only relevant macro factors. One way to design a stress test would be to impose a combination of high interest rates, high inflation, low economic growth and weak house-price growth on the model and then see how the portfolio behaves. Perhaps you could tip your hat to history by using figures from specific percentiles of the observed distribution of the data. The problem with such an approach is that sustained high interest rates are inconsistent with sustained high inflation and sustained high inflation is inconsistent with sustained weak economic growth and weak house-price growth. Further, sustained weak growth will probably trigger interest rate cuts, meaning that high rates are likely to be inconsistent with a sagging economy. Non-economists will tend to gravitate to these types of ridiculous future scenarios. Interestingly, given that realistic economic scenarios tend to contain both mitigating and exacerbating factors, the naïve approach is likely to overstate the impact of the underlying shock and lead to estimates of capital requirements that are unnecessarily and unreasonably high given the Basel II stipulations.

Another naïve error would come from simply replicating past events. The Basel II documentation does mention "historical" scenarios but we feel that this should be interpreted very carefully. One could, for example, apply a rerun of the 1973 OPEC oil embargo to a modern macro model but it is unclear whether this would actually achieve anything useful. The shock that occurred back then was probably of an appropriate magnitude for valid stress testing but it was applied to an economy saddled with multiple layers of regulation and various other severe market rigidities. It generated a combination of outcomes—9% unemployment and 12% inflation—that are unthinkable today, given the shock absorbers in place throughout the economy. Even replicating the magnitude of past disasters may therefore be dangerous when applied to currently applicable stress tests. Past superlatives like 1973 are just not realistic any more; the external shock needed to generate these types of outcomes would have to be of a comet strike severity. Even shocks from the relatively recent past seem strangely quaint today. The world has moved on from events like the tech bust and the Long Term Capital Management collapse. The next shock will be something different; it will just feel like déjà vu all over again.

Both of these naïve stress test designs ignore the existence of equilibrating forces in the economy generally and in the credit sector specifically. In order to run stress tests correctly, a structural, general equilibrium model of the economy, a current understanding of the risks the economy faces and a lot of experience of past stressed circumstances are the required elements.

Stress testing the West Chester way

In order to explain our approach to stress testing, we will develop a hypothetical situation where we are working with a client with a mortgage portfolio who seeks to develop a stress testing protocol for Basel II compliance. We will assume that the client is from a fully developed country (the U.S.) and has a data base typical of banks in this situation. Naturally, these circumstances are somewhat idealistic and, in reality, aspects of the optimal approach will be selected to suit specific circumstances or data limitations. Any similarity to banks, living or dead, is purely coincidental.

To conduct the stress test, we need three components:

- A structural macro model like those that already drive Moody's Economy.com's forecasting practice.
- A standard credit risk model, be it a PD, LGD (Loss Given Default) or EAD (Exposure at Default) specification, that applies to individuals within the credit risk framework.
- A means through which the credit risk model can be correctly interfaced with the structural macroeconomic model.

In large measure, the latter two components were described earlier. The point is that we have an aggregate model of the portfolio's performance that matches the aggregation level of the structural macro model being employed. We then have an individual level scoring model that can be calibrated to match the outcome derived from the aggregate portfolio model.

One problem that should be addressed is that the portfolio will behave differently while under stress than it will while at rest. Consider the following example. Suppose we are interested in testing athletes for a (hypothetical) performance enhancing substance called phasterol, which occurs naturally in the body in small amounts. In the general population, it is found that diabetics have 3.2 times as much phasterol in their blood than those who do not suffer from the affliction. Following a marathon, one runner is found to have 8.3 times the natural level of phasterol in his sample. His only defense is that he is a diabetic.

The problem here is that we do not know how the test behaves when the subject is under stress. The parameter measured at 3.2 in the general population may not apply to marathon runners who are putting their bodies under considerable strain; 8.3 may in fact be a more accurate diabetes factor. If this runner is banned on this "evidence" alone, a miscarriage of justice is very likely.

Stress testing in finance is exactly the same. Based on historical data we may observe, after controlling for a number of

factors, that a percentage point increase in the unemployment rate boosts the probability of default by 60 basis points. This figure is derived from history during which an average amount of stress was brought to bear. Under extreme stress, there is every chance that 60 will become 30 or 100; this discrepancy could make a big difference on the result of the eventual stress test. Individual level scorecards could also behave differently when faced with stress than they do under baseline economic conditions and this should also be considered. The approach taken should reflect stressed circumstances at all measurement points lest a bank's portfolio test positive for insolvency causing it to be erroneously banned from future competition in the credit Olympics.

There are two ways of dealing with this issue from a modeling perspective. The first is by parameterizing the various models involved in the stress test so that economic variables influence the marginal effects of changes in the explanatory factors. By doing this, the stressed economic scenario could be allowed to influence the slopes or elasticities of the various relationships described by the model.

The second approach involves taking a more semi-parametric view of the problem. One way of thinking about stress is as tail events in the historical conditional distribution of the data. By this we mean that the sum total of all the unobserved factors that influence mortgage default detract from performance, implying that default outcomes are surprisingly bad given the included factors. By using semi-parametric techniques that are well-known in the econometrics literature we can determine the marginal impact of shifts in the explanatory factors at various percentiles of the distribution. Doing this allows us to model the performance of the portfolio under circumstances that are not particularly conducive to sound credit compliance.

Next, the issue of exogeneity of the economy to the portfolio must be addressed. The current subprime mess neatly demonstrates how credit default behavior can feed back into the economy and affect macroeconomic outcomes. Generally, specific portfolios of small individual lenders will be able to be treated as price-takers who are simply unable to influence the behavior of the rest of the industry or of the economy. If the entire industry runs as a herd, however, then the economy can be affected, leading to feedback loops that impact the portfolio through the usual macroeconomic channels. The way we suggest to address this issue is to include relevant industry level statistics in the structural macro model, which we already do, and then, at the portfolio level, assess whether the client's position relative to the entire industry is likely to change should the stressed circumstances actually occur.

In the current environment, from the perspective of our hypothetical mortgage lender, a stressed set of circumstances already exist. Conditions, particularly at the subprime end of the industry, are grim and we have already seen many companies become insolvent as a direct result of macro level events. They have thus failed the ultimate stress test, also known as reality. A valid question under such circumstances is whether the stress test scenario needs to differ in any way from the baseline economic forecast given that even this implies difficult conditions for the subprime mortgage sector. Unfortunately, there is still a lot more that can go wrong for mortgage companies and a valid stress test for surviving entities should reflect this. In the current environment, wise companies will want to know whether they could survive if things became even worse. Static concepts like a "one-in-25 year recession" should be thrown out if you already are in such a predicament. For subprime mortgage lenders today, a one-in-100 year scenario would probably be a more relevant downside experiment and this might even be required given the precise wording of the Basel II documentation.

The stressed macroeconomic environment we would apply for a mortgage lender at present would look something like the following. The greatest current threat for mortgages is an outbreak of inflation. We have recently seen a 50 basis point rate cut by the U.S. Federal Reserve designed to relieve the credit crunch conditions despite the fact that they were retaining a rate hike bias even at the preceding meeting. A nightmare scenario involves a significant breakout in inflation, perhaps driven by record high oil prices and fanned by looming further Fed rate cuts. Under the central bank's mandate, Chairman Bernanke would be required to act boldly in these circumstances to maintain control of prices, which, after all, is any central bank's raison d'être. The subsequent tightening in monetary conditions would be like kryptonite for the mortgage industry, ostensibly kicking it while it is down. Such a scenario seems to be a manifestation of Murphy's Law—that which can go wrong will go wrong—but that is the nature of stress testing in an already stressed environment.

The outcomes stemming from this nightmare scenario would then be applied to the rest of the economy via our macro model. Naturally, if these events unfold, a deep recession would be inevitable. House prices would plummet and unemployment would skyrocket, further compounding the difficulties of the mortgage sector specifically. Inflation really is the ultimate exacerbating economic factor in any situation—if price growth surges, there really is no upside.

If we were stress testing a credit card portfolio, on the other hand, the macroeconomic environment would not need to be quite this extreme. From the card industry's perspective, the worst of the current situation still lies ahead; you never know, the fallout from subprime mortgages may even completely pass them by. There have been some issues emerging in the sector with a number of firms announcing significant layoffs and with the economy-wide credit crunch crimping their ability to boost business. At least according to our data, however, delinquencies and defaults in cards, although rising, are still below long-run average levels. The other point is that the credit card sector is driven by very different factors than the mortgage industry. While mortgages are deeply affected by house prices, cards are more closely dependent upon income and wages growth and the financial obligations being faced by households. A stress in this sector might see the housing crisis spill over into higher rents as first-time homebuying slows to a trickle in the face of tight cred-

it and low housing affordability. If you combine a scenario along these lines with the usual recessionary macro situation involving substantially steeper unemployment and poor income growth, it is a recipe for much higher credit card delinquency and default. The only problem is getting the magnitudes right, which is where the structural macro model proves to be an invaluable asset.

Other product types like home equity lines of credit, autos and student loans will behave differently again and face different kinds of future downside stresses. The important thing is to have a solid, generic, most likely recession scenario on hand and then modify it to highlight the specific characteristics that are of particular concern to the industry in question.

Conclusion

There seems to be considerable unease in the industry about how best to implement a comprehensive stress testing regime. In a way, given that few credit professionals are expert macroeconomists, this is quite understandable. From an economist's perspective, meanwhile, the issue of stress testing is a natural one to address. We are constantly asking "what if" type questions involving downside risks to our forecasts and we are always on the lookout for conditions that may spark a future recession. The only sticking point is finding a way to combine our top-down macro models that reflect stressed macroeconomic environments with the bottom-up models typically applied in the retail credit sphere. The blueprint discussed here, if implemented appropriately, would allow a bank to overcome these difficulties and paint a picture of their portfolio perturbed by significant external sources of stress.

Of course stress testing is only one important part of Basel II. If we assume that recessions hold the potential to impact credit portfolios and subsequent capital reserve requirements, we should also account for baseline macroeconomic conditions in assessing "normal" capital adequacy provisions. There are no obvious reasons why the models used to conduct stress tests should not also be employed for the purpose of constructing internal ratings of risky exposures. The simple fact is that economics affects credit not only in the extreme but also at the margin. The full incorporation of macro factors in individual level models is therefore paramount. No man is an island after all. It would be a monumental task to correctly account for the way macroeconomic shifts affect every individual in the sample, but assessing the way the macro economy shapes the overall portfolio, viewed as a single entity, is far more tractable. The logical approach is to do this modeling at the aggregate level and only then worry about how individuals in the sample relate to the collective.

These types of questions are important because specific risky individuals are unlikely to send multiple lenders, or even individual companies, to the wall. Industry-wide shocks, herd behavior and recessions are far more dangerous risks to the overall solvency of complex consumer credit portfolios. The current situation with subprime mortgages should be the only evidence required to focus the attention of financial institutions on the importance of correctly modeling how economic trends affect their portfolios.

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Tony Hughes is senior director of Credit Analytics at Moody's Analytics, where he manages the company's credit analysis consulting projects for global lending institutions. An expert applied econometrician, Dr. Hughes also oversees the Moody's CreditCycle and manages CreditForecast.com. His varied research interests have lately focused on problems associated with loss forecasting and stress-testing credit portfolios.

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A former academic, Dr. Hughes held positions at the University of Adelaide, the University of New South Wales, and Vanderbilt University and has published a number of articles in leading statistics and economics journals. He received his PhD in econometrics from Monash University in Melbourne, Australia.

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Economic & Consumer Credit Analytics

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Moody's Analytics added Economy.com to its portfolio in 2005. Its economics and consumer credit analytics arm is based in West Chester PA, a suburb of Philadelphia, with offices in London and Sydney. More information is available at www.economy.com.

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