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Chapter 3: Mapping China’s Macroeconomic Chronology

When I first started as an investment analyst, I took wisdom from Joseph H. Ellis, author of *Ahead of the Curve* and veteran analyst at Goldman Sachs. In his book, Mr. Ellis summarized his analytical methodology into a flowchart, as shown in Figure 3-1.

He explained that consumption drives the US economy. The simple logic is that when the job market goes up, employment and personal income go up. When people have more disposable income, they buy more and drive up consumption. Higher consumption motivates companies to produce more goods and provide more services. And at some point, production reaches its capacity limit, so companies need to invest in fixed assets to expand their manufacturing capacity. Higher consumption also increases company revenue and companies may then raise payroll expenditures, which, in turn, increases the personal income of households, meaning the employees of companies. This describes an economic/business cycle. And of course, there are other less essential causal relationships, e.g., interest rates can also affect consumption by encouraging or discouraging borrowing. If companies earn more money, their share prices go up, thus creating more fortune for households’ financial asset portfolios such as pension plans, which again, motivates consumption. The pillar of the US economy is, without any doubt, consumption.

As explained in *Ahead of the Curve*, to analyze the macroeconomy, we need to find a series of leading and lagging indicators to map out the chronology of business cycles. Furthermore, after we successfully map out the chronology, we hope to find how interest rates move with the business cycle.

I tried to create a similar flowchart for analyzing the macroeconomic fundamentals of China. Being a rates strategist, I was often asked by clients to make a prediction about the economy in three to six months. I found a clear chain of cause and effects, which starts from real estate sales, through real estate investments, and ends with industrial production and manufacturing investment. A proposed framework for analyzing China’s macroeconomic status is presented in Figure 3-2. As we shall see later, the key determinant of market rates is industrial output, and industrial output is driven primarily by cycles of the real

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| Source: Ahead of the Curve (Ellis 2005) | **Analytical Framework of the US Economy** | **Figure 3-1** |

estate industry, among other less important factors. The framework is a simplified one but often helped me stay a few steps ahead of the market. I will explain each part of the framework in detail in later chapters.

As discussed, the foundation of the US economy is, without a doubt, consumption. That’s why every month we have an exciting moment when the US non-farm payroll data is released. So, what is the bedrock of China’s economy? The answer is real estate. Real estate, along with a few other less important factors, is the engine of China’s economic growth. Here is the general chronology of a Chinese economic cycle:

* Three chains lead to growth in industrial production. The first and most important one starts with real estate sales.
* Real estate sales are the primary driver of real estate investment. The more houses that real estate developers sell, the more they can spend on new land. And, the more land they own, the more buildings they can construct.
* The development of houses, apartments, shopping malls and office buildings can involve other manufacturing industries and lead to growth in industrial production. We can predict industrial production by looking at real estate sales and real estate investment in the past few quarters.
* The second most important chain is through export. Unlike the real estate chain, which could last nine to twelve months before growth in real estate sales start to push up industrial production, the export chain is short. Manufacturers keep a low level of inventory for foreign buyers. They put their factories to work directly after receiving orders from foreign clients. If we can find a way to predict export, we can predict industrial production.
* Growth in industrial production increases corporate profits and, in turn, leads to higher employment and salaries. When consumers have more money, they are likely to increase spending.
* Lastly, growth in consumer spending can also increase industrial production. The causal relationship between consumption and production is less clear because China has never been a consumption-driven economy. But in recent years, consumption is picking up steam as Chinese policymakers are trying to transform the economy to let domestic demand drive

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| Indicators with monetary values are in nominal terms, i.e., not adjusted for inflation. | **Analytical Framework of the Chinese Economy** | **Figure 3-2** |

the business cycles.

* The interest rate movements, which reflect changes in the macroeconomy, are synchronous with industrial production. If we can get an accurate forecast on industrial production, then we are ahead of the market and can ride the yield curve to make money.

Each of these indicators occupies a sequential position in the business cycle which has repeated itself over and over for the past few decades. Some indicators appear to be more prominent in some cycles, but the overall pattern holds.

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**Real Estate Is the Cornerstone**

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| **Figure 3-3** |
| **The Importance of Real Estate Industry** |
| Source: Wind Database |
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Criticized by economists across the world, China’s economic development mainly relies on the prosperity of the real estate market since 2002. Unlike the US economy, China’s economy is driven by investment rather than consumption. The bulk of investment in China is not derived from the increase in household income but mainly from profit accumulated from trading commercial and residential buildings. For example, a real estate firm purchases a piece of land from the government, builds houses or apartments on it, buys all sorts of industrial goods for construction and creates profits for other manufacturing companies. From that point, China’s economic cycle is similar to the US economy when manufacturers expand production as the real estate market grows.

The real estate market always grows because there are 1.4 billion people in China with an ingrained culture that promotes property ownership as a symbol of adulthood. Also, years of monetary easing have been pushing up property prices but, in the meantime, lowering borrowing costs for the real estate companies.

How does the real estate industry become the bedrock of the manufacturing economy? The combination of real estate and construction historically account for over 15% of China’s GDP, as can be seen in Figure 3-3.

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| **Table 3-1** |
| **Real Estate Has Many Related Industries**   |  |  | | --- | --- | | **Upstream Industries** | **Downstream Industries** | | Steel Industry  Energy Industry  Chemical Industry  Construction Industry  Machinery Industry  Transportation Industry  Financial Industry  …… | Electronic Appliances Industry  Construction Material Industry  Decoration Industry  Property Management Industry  Furniture Industry  …… | |
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Let us do a thought experiment to help us better understand the relationship between real estate and the manufacturing industry. To build a house, we need to buy steel, concrete, cement, etc. We need trucks to carry heavy materials from spot to spot and cranes to lift the steel to the top of the building. We need plastic pipelines for running water and wires for electricity. After the construction is done, we sell the house to a newlywed couple, who will finance the house with a mortgage. They will paint the rooms and maybe install a security system. Then, they would fill the rooms with furniture, kitchenware, beddings, etc. Their parents or in-laws may send them a fridge, microwave oven, or washing machine as wedding gifts. These goods account for a significant portion of the steel industry, furniture industry, electronic appliances industry, heavy machinery industry, chemical industry, etc. And those are only the most basic materials and furnishings of a home. The housing industry is among the few industries that involve an extensive, sophisticated supply chain, making it a likely candidate for the bedrock of an industrial economy. Real estate has a lot of upstream and downstream industries, as we can see in Table 3-1.

China shocked the world by the incredible pace at which it moved from an agricultural economy to a light-industrial economy and then to a heavy-industrial economy in just under forty years. In the 1980s, it was the light manufacturing industry instead of the real estate industry that moved the economy. As China evolves into a more advanced country, the dominating industry may change again. Nevertheless, China’s economy is expected to be largely driven by investment and export rather than consumption in the foreseeable future because Chinese nationals have a deep culture of saving rather than spending. It will take generations and huge changes in societal structure to bend that habit.

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**Finding the Leading Indicators**

In commercial macroeconomic analysis, we constantly look for leading indicators. If series A leads series B by six months, we could use A to predict B. For example, as we shall see later, if real estate sales reversed a downward trend, we could expect real estate investment to pick up steam in two to three quarters. By definition, as shown in Figure 3-4, if the *turning point* or *inflection point* of series A always shows up before that of series B, then A is considered a leading indicator of B. And naturally, we conclude that a cause-and-effect relationship exists between A and B.

The question is how we can decide which leads which? A classic example to illustrate this problem is the relationship between consumer spending and corporate profits. On the one hand, higher consumer spending increases companies’ sales revenue and leads to higher profits if the profit margin does not change dramatically. On the other hand, higher corporate profits would encourage the managers to increase employees’ salaries and hire more staffs. This, in turn, gives the residential sector more money to spend and increases consumer spending. How do we decide which effect is stronger? The most efficient way to decide that is to chart both indicators in a graph for as long as possible. The longer the chronological pattern holds in the history, the more confident we are about the leading and lagging relationship.

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| **Figure 3-4** |
| **The Nature of Leading Indicators** |
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A second question is how can we be sure that leading-and-lagging relationship means a cause-and-effect relationship? As we often say in statistics, ‘correlation is not the same as causality.’ There are a few methods in statistics to test causality, but in commercial macroeconomic analysis we rely on two criteria. First, the cause-and-effect relationship must comply with economic theory. A ridiculous counterexample is shown in Figure 3-5 as we chart the number of films starring Nicolas Cage and the number of people who were drowned in a swimming pool. It would be both funny and offensive to conclude from this chart that Nicolas Cage’s performance encouraged people to drown themselves. In this case, the relationship clearly has no logical ground. We should always check the economic logic before making an inference about causality. Secondly, the leading-and-lagging relationship should be apparent and lasting. In macroeconomics, that means the relationship must hold from cycle to cycle. If both conditions are met, we can conclude causality. This, of course, isn’t the standard for academic economists. But as a reminder, the ultimate criterion to judge an investment analyst’s work is by his prediction accuracy. Sometimes, we sacrifice a little academic rigor to improve our prediction abilities.

A third problem is that the length of the lag between two indicators may change from cycle to cycle. There is no good way to solve this problem except for closely following the data of the lagging indicator to make a more informed guess. But the actual moment of the turning point is much less important than the advanced notice that a turning point is due. Investment is more like a marathon than a sprint. We can’t expect to always capture the right moment to adjust the portfolio. Fuzzy correctness is good enough in most scenarios.

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| **Figure 3-5** |
| **Correlation Doesn’t Always Indicate Causality** |
| Source: US CDC, IMDB, Spurious Correlations |
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**Nominal vs. Real**

For bond investors, we should be aware of the distinction between nominal economic variables and real economic variables. The nominal value of any economic indicator means that we measure the statistic in terms of actual prices that exist at the time, while the real value refers to the same indicator after it has been adjusted for inflation. In *Ahead of the Curve,* Mr. Ellis emphasized the importance of using real economic variables in making forecasts about the stock market, but that axiom changes if what we forecast is the interest rate movement. For equity strategists, real variables such as real gross domestic product (GDP) are more critical because real variables give us the essential information about the economy’s future. Since equity investment is about the upside of companies and sectors, it makes sense that real economic variables play a more prominent role in equity strategy research. In rates strategy, we often look at nominal variables; we care much more about inflation because bond investors have a shorter investment horizon. Within that relatively shorter investment period, we will ask for a return higher than the inflation rate. As we shall see in later chapters, market rates are often driven by nominal economic variables rather than real economic variables.

Common knowledge dictates that the stock market rises when the economy is good, and the bond market rises when the economy is bad. But when real GDP growth exceeds expectation, the bond market does not necessarily plunge. If the economy is in deflation, then it’s possible to have both higher than expected real GDP and lower than expected nominal GDP. Interest rates move in accordance with nominal GDP instead of real GDP.

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**Dealing with Data Deficiency**

Before we go into charts and models, we should brace for a major challenge in China: the lack of data. China doesn’t have a lot of data vendors; thus, we often rely exclusively on one source of data, the government. If the government fails to provide, or worse, manipulates the data, we cannot make meaningful forecasts. This is incredibly frustrating for data scientists and model enthusiasts.

The most challenging issue is the lack of employment and household income data. China only started to record employment and personal income in the 2010s, and the data quality could not be worse. China’s unemployment rate has been significantly lower than that of most developed economies; even in the most dire periods, the unemployment rate seldom exceeded 6%. The number looks good, but Premier Li Keqiang, who holds a Ph.D. in economics, seemed obsessed with China’s unemployment problems when he appeared on TV in recent years. During the Covid-19 pandemic, China’s unemployment rate rose to 6.3%, which was still excellent considering the scale and impact of the global pandemic. But Premier Li went to such great lengths to save employment that he lifted the decades-long ban on street grocery carts and let people sell groceries wherever they wanted. It was a big deal in China. It begs the question, why was he so concerned about unemployment when the statistics clearly showed everything was alright?

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| Source: imgflip.com |
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The answer is that the official unemployment data was unreliable and Premier Li must be using other data sources to support his policy. The full terminology for unemployment rate is Urban Surveyed Unemployment Rate, which only records unemployment in urban area. However, a large portion of the Chinese population is not considered urban. China has a household registration system, in which every person must be registered as either urban or rural. As China’s cities grow, rural people migrate from farms to cities to work as delivery boys, builders, cooks, etc. When the economy plunges, many rural workers lose their jobs in the city and can no longer afford the city’s high rent. So, they return to their rural homes. But the employment survey does not count those returners because there are too many rural-registered people migrating from farms to cities, and it is impossible to track them. When a rural worker loses his job in the city and is forced to return to his rural home, he is automatically considered returning to his home to become a farmer again, which is a kind of employment. According to the National Bureau of Statistics, 41.8% of the population is rural. So, leaving rural-registered communities out of urban employment surveys leads to a substantial statistical discrepancy.

Premier Li is a seasoned economist. He understands the flaws in statistics. Without reliable data on employment and income, we cannot forecast personal expenditure. Luckily, consumption has not become the pillar of China’s economy yet. Even without employment and income data, we can still capture the trend of China’s economy by analyzing industrial production, investment and export. Still, it is frustrating when you have an idea of the causal relationship between some economic indicators but the data to test your hypothesis is unavailable or nonexistent.

Unlike the long record of detailed data in the US, China’s data archive dates back to the 1990s, with a few critical data absent until 2002 when China began to open its domestic market to foreign investors. I expect that we will have more comprehensive and detailed data archives as the market attracts more and more investors, but for now, we can only work with what we have.

In the next part of the book, I will break down the general framework and examine the cause-and-effect relationships from block to block.

Part 2: Breaking up the Economy

Chapter 4: The Real Estate Chronology

Figure 4-1 presents the chronological order of the real estate cycle. Real estate companies purchase more land in response to higher sales in the previous quarter. China’s law prohibits real estate firms from using borrowed money to buy land. Although rampant shadow banking in 2013 to 2017 breached this law in some cases, the cash collected from sales of properties is still the dominant source of funds for land purchasing. As a result, real estate companies plan their land purchasing according to their sales revenue, which makes real estate investment a lagging indicator of real estate sales.

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| **Figure 4-1** |
| **The Real Estate Chronology** |

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| **Figure 4-2** |
| **Schematic Diagram: Real Estate Sales and Land Purchase**    **An uptrend in real estate sales provides real estate companies with more funds for land purchase. Land purchase usually lags real estate sales for about one or two quarters, depending on the land market conditions.** |
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| **Figure 4-3** |
| **Real Estate Sales Lead Land Purchase**  Source: Wind Database |
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**Real Estate Sales Drive Land Purchase**

Figure 4-2 presents the schematic diagram of real estate sales and land purchase. Land purchase can be measured by land transaction fees. This leading-and-lagging relationship exists for two reasons. An apparent reason is that after collecting enough funds from sales, real estate companies need some time to select a site for development and maybe another couple of weeks to seal the deal. Another reason for the long gap is mortgage payments.

The typical process of buying an apartment in China is that you sign a contract with the property seller, pay a down payment (usually thirty to forty percent of the total price) and apply for a mortgage. Then, the realtor draws up paperwork for government registrations, and the two parties sign a set of standardized documents to make an official ownership transfer at government agencies. Finally, the bank releases the mortgage payments to the seller after it sees the government registration documents. The last step usually takes at least three months and often longer when market liquidity is tightened. Provinces and cities have their own rules on how long banks have to release the funds to property sellers. In most cities, the law favors the bank, and banks usually have more discretion in deciding when to pay the real estate companies. Figure 4-3 proves the relationship between real estate sales and land purchase.

We could further break down the above process by adding the step of collecting funds to the chronology. Real estate companies collect funds from sales of properties and then buy land through government auctions. The funds for land transactions and building construction in the future is recorded by an indicator called ‘the real estate development funds.’ Figure 4-4 demonstrates the gap between sales and the real estate development funds. It’s not surprising that the real estate development funds lag behind real estate sales for about a quarter. Notice that from 2012 to 2014, property sales and real estate development funds coincided. The central bank adopted a loosening monetary policy at that time, and there was abundant liquidity.

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| **Figure 4-4** |
| **Real Estate Sales Slightly Lead Real Estate Development Funds**  Source: Wind Database |
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After securing enough funds for new development, real estate companies bid for land from government auctions. As shown in Figure 4-5, the real estate development funds slightly lead land transactions.

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| **Figure 4-5** |
| **Real Estate Development Funds Slightly Lead Land Purchase**  Source: Wind Database |
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Land transaction fee capture the monetary value of land, but it is different from the actual amount of cash paid by real estate companies to the land seller. In most cities, the local government allows real estate companies to pay for the land in installments. The land transaction fee is the land’s monetary worth in the contract, but it is not always equal to the exact amount of cash paid on the transaction day. Since the 2008 financial crisis, an increasing number of cities allow real estate companies to pay fifty percent of total value at the transaction day and the remaining fifty percent within six months. The actual amount of cash paid by real estate companies for land purchasing is recorded in another statistic, the ‘real estate investment (other expenditure).’ So, it is not surprising that land transaction fees led real estate investment (other expenditure) in recent years (Figure 4-6).

Another way to measure the land transaction is to use the planned construction area directly, e.g., the 100 Large & Mid Cities Planned Construction Area. Planned construction area is the total floor space in the building plan when real estate companies bid for land. This data is smoother compared to the land transaction fee (Figure 4-7), thus easier to capture long-term trends. Unfortunately, historical data of

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| **Figure 4-7** |
| **Land Transaction Fee Coincides with Planed Construction Area, but Planned Construction Area Data Is Smoother**  Source: Wind Database |
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| **Figure 4-6** |
| **Land Transaction Fee Leads the Actual Cash Expenditure for Purchasing Land**  Source: Wind Database |
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planned construction area does not exist before 2009.

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| **Figure 4-8** |
| **Schematic Diagram: Land Purchase and Real Estate Investment**    **Real estate investment gains traction following an uptrend in the land purchase. The lag is usually two to three months. Volatile swings in the land transactions usually only drive moderate changes in the real estate investment.** |
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After acquiring the land, real estate companies generally start to build properties on it within two to three months. Real estate investment is the total expenditure related to buying land, constructing buildings, buying equipment and in-house installations. Figure 4-8 shows the schematic diagram of land purchase and real estate investment. In terms of year-over-year growth, real estate investment is less volatile than land purchase.

As shown in Figure 4-9, our empirical look at the actual relationship between land purchase and real estate investment is clear. Real estate investment lags land purchase for about a quarter and is much less volatile comparing to land purchase.

According to the National Bureau of Statistics, there are four sub-categories within real estate investment. Figure 4-10 shows the four types of real estate investment and their proportions. Construction investment is the biggest real estate investment, and land purchasing comes second. The land purchasing costs in the real estate investment could be slightly arbitrary since the real estate companies have some discretion in paying the installments. But Figure 4-9 shows that the casual relationship between land transaction and the total real estate

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| **Figure 4-9** |
| **Land Transactions Lead Real Estate Investment**  Source: Wind Database |
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| **Figure 4-10** |
| **Four Sub-Categories of Real Estate Investment**  Source: National Bureau of Statistics |
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investment is good enough to make meaningful inferences. We could also extract only the construction and installation investment to make a similar chart. Figure 4-11 shows that if we chart land transaction with construction and installation-related investment, the causal relationship still holds, with a short period of anomaly in 2018 when real estate companies put construction on hold to rush into land auctions as the land market was overheating. Many of the most expensive lands in China’s history were purchased during this period.

The reason for charting only construction and installation investment is that these two classes of investment directly involve industrial goods consumption; hence, they are more likely to be used to forecast industrial production. We will see this later.

Another way to predict construction and installation investment is to look at the new construction area. New construction area measures the floor space that just went into construction. A higher growth in the new construction area indicates higher growth of construction and installation investments (Figure 4-12).

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| **Figure 4-11** |
| **Land Transaction Leads Real Estate Investment (Construction & Installation)**  Source: Wind Database |
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In this chapter, we went through the real estate cycle. China’s real estate industry has a clear chronological chain starting with commercial real estate sales and ending with building constructions. Real estate industry is the engine of China’s economy. Readers may find that the volatility of each real estate cycle, represented by the volatility of real estate sales, has been decreasing in the past decade. But the real estate industry is unlikely to relinquish its core status in the economy to other industries, because real estate is by far the only industry that involves such a long supply chain. No other industry can beat that. Macro-analysts should carefully follow data of the real estate industry.

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| **Figure 4-12** |
| **New Construction Area Leads Construction and Installation Investment**  Source: Wind Database |
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Chapter 5: Real Estate and Financing Activities

Financing activities fluctuate synchronously with real estate sales, and both interest rates and monetary policies interact with financing activities (Figure 5-1).

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| **Figure 5-1** |
| **Real Estate Sales and Financing Activities Reinforce Each Other** |
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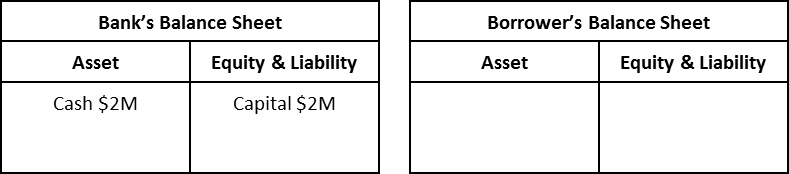
There are a few methods to measure financing activities. The three indicators used most in China are M1, M2, and aggregate financing to real economy (AFRE, also known as total social financing). The definition of each of these three indicators is listed in Table 5-1.

First-year analysts often have a hard time understanding why M1 and M2 measure financing activities. This is especially so for those who come from non-financial majors, such as me. Indeed, M1 and M2 are indicators for money supply and are calculated from bank deposits. How are they related to lending? In fact, in a credit money system, loans create deposits; thus, money supply equals financial borrowing. Even if a bank has no cash, it can still issue loans in a credit money system.

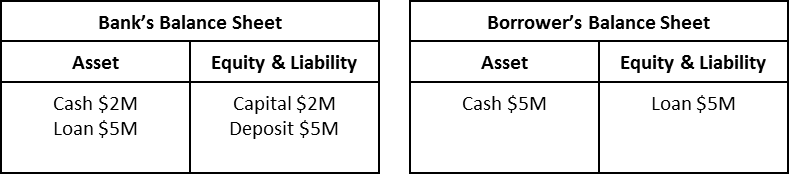
However, in a material money system, the common understanding is that people deposit their money in banks, and then banks use the money to issue loans. Thus deposits (money) create loans (credit). Under this framework, the amount of money supply decides the amount of credit in the economy. This was true in ancient times when people used medal as the currency for trading, but we no longer use gold, silver or any material as currency. What we now use to make payments are figuratively just numbers on a computer screen. If the amount of material money limits the amount of credit, then as the economy grows, we will have a shortage of credit at some point. Hence why we abandoned the material money system long ago and replaced it with the credit money system.

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| **Table 5-1** |
| **Financing Activities Definitions**   |  |  | | --- | --- | | **M1** | M1 comprises currency in circulation plus demand deposits in national currency of resident non-bank non-government sectors with the PBoC and banking institutions. Currency in circulation refers to notes and coins by the PBoC less the amount held by banking institutions. | | **M2** | M2 comprises M1 plus time and savings deposits in national currency of resident non-bank financial corporations and non-bank non-government sectors with the PBoC and banking institutions. | | **AFRE** | Aggregate Financing to Real Economy refers to the aggregate volume of funds provided by China’s domestic financial system to the private sector of the real economy. AFRE includes indirect financing via the banking system and direct financing via stocks and bonds on the capital market. |   Source: People’s Bank of China, Federal Reserve Bank of St. Louis |
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In the credit money system, a bank can create loans and money by changing its balance sheet. Let’s use a simplified model to illustrate the difference between a material money system and a credit money system. Suppose there is only one bank and one borrower in the market. The bank has a total capital of two million dollars while the borrower has nothing at the start. So, in the beginning, their balance sheets look like:

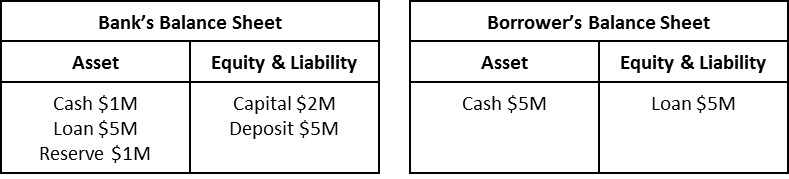


The borrower wants to borrow five million from the bank. It won’t happen in a material money system because the bank only has two million dollars in cash. But in the credit money system, the bank sees an increase of five million in both its asset and liability, as does the borrower. The balance sheets then look like:



Notice that the bank’s liability now has five million of deposit. When the bank gives the loan to the borrower, the borrower automatically deposits it into his savings account at the bank. He could, of course, withdraw the five million to pay for a seaside resort, and in that scenario, the bank would need to sell some of its assets. The borrower now has five million worth of cash and five million in debt owed to the bank. In this process, the bank creates money by writing a loan to the borrower.

In the example above, the bank has the power to create as much money as it wants, and the only constraint for the bank is to evaluate if the borrower can service his debt. This mechanism erodes the government’s capability to regulate the economy. If banks can create unlimited money, they could quickly overheat the economy. Therefore, governments require banks to have deposit reserves, which is the amount of cash that banks are required to deposit at the central bank. Suppose the required rate of deposit reserve is twenty percent, which means that the bank must deposit at least twenty percent of the deposits on its balance sheet at the central bank. Some central banks pay interests on deposit reserves. The deposit reserve is recorded as an asset on the bank’s balance sheet. In that case, the balance sheets become:



Since the bank initially had two million in cash to begin with, the maximum amount of loans it can write to its clients is two million divided by twenty percent, or ten million dollars ($2M/20%=$10M).

This simple illustration explains how money is created in a credit money system. Of course, this is an over-simplified model of the credit money system. In reality, banks can’t just arbitrarily change the numbers on its balance sheet, but instead, the borrowed money needs to be deposited into the bank before the bank can use that money to issue another loan. Also, there is still hard material money in the credit money system, but credit-created money now accounts for over 90% of the total money supply. It’s safe to say that studying deposits (money) is almost parallel to studying credit or financing activities, as most money is created by financing activities. Thus, analyzing M1 and M2 is vital to macroeconomists.

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| **Figure 5-2** |
| **Real Estate Sales Coincide with M1**  Source: Wind Database |
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In an era of industrial economy, real estate sales and financing activities are the two most important indicators to follow. Looking closely at the trend of these two data, you can find that they are actually one; that is to say, real estate sales and currency growth are mutually causal and mutually reinforcing.

Figure 5-2 is vivid proof of how important real estate is in China’s economy. Real estate-related borrowing accounts for a significant portion of total financing, which is why M1 and real estate sales tend to move coincidentally.

M1 mostly consists of demand deposits, which are the bulk money used in business dealings. China’s M1 doesn’t include the residential sector’s demand deposits and only includes deposits from the business sector. Without the white noise from the residential sector, M1 becomes an excellent indicator to measure business activities. There used to be a saying in China’s capital market, ‘M1 decides trading,’ which means that the highs and lows of M1 growth rate determine the tops and bottoms of the stock market.

M2, on the other hand, contains time deposits, which are not commonly used in real economy business. Time deposits, especially those that mature in over one year, tend to flow into the capital market instead of the real economy. When the growth rate of M2 significantly exceeds the nominal GDP growth rate, both stocks and bonds rise. When analyzing the bond market, we should carefully study the M1 cycle and make forecasts.

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| **Figure 5-3** |
| **Real Estate Sales Coincide with AFRE**  Source: Wind Database |
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As we have explained, borrowing/credit creates money. We have seen how money moves with the real estate cycle. So, what about the credit side? Figure 5-3 shows how aggregate financing to real economy (AFRE) moves with real estate sales. The coincidental relationship is not as strong as that seen in Figure 5-2 because AFRE not only contains credits for business activities but also for other uses such as capital market investments and credit card bills. Since October 2019, the National Bureau of Statistics has expanded AFRE to include treasury bonds. The fiscal deficit is mostly driven by infrastructure investment, which is counter-economic cycle, meaning infrastructure investment tends to go up when the macroeconomic condition deteriorates. The adjustment was back-dated to 2017, which is why in Figure 5-3, there is an anomaly with the coincidental relationship in 2017 and 2018.

In the past fifteen years, people who bought houses in China have won out as houses are increasingly accruing value, a destiny inseparable from China’s industrialization process. Because the Chinese economy was driven by debt and real estate during the industrialization period, the two strengthened each other. This made real estate the core of the economy and credit, as well as the main source of wealth for residents. But as rapid industrialization is coming to an end, the source of wealth creation will also change accordingly. It is possible that at some point in the future, real state might give way to a new industry as the keystone in China’s economy. Nevertheless, if this change happens, we can always use M1 as a starting point for macroeconomic analysis because every business, whether it is real estate or high-end manufacturing, needs to borrow money from the banks to finance its operations and expansions.

Lastly, monetary policy also plays a significant role in determining financing activities. In my opinion, monetary policy is like a rope. You can use a rope to pull but not push. When the economy is overheated and borrowing becomes fanatic, like in 2003, 2010 and 2016, tightening monetary policy could effectively cool things down. But, when the economy is underheated and demand is low, loosening monetary policy hardly increases the demand for credits in China. Usually, when the PBoC fights floppy demand with loosening monetary policy, the capital market gets most of the liquidity while the real economy only receives a small share. It’s always easier to kill demands than create them. We discuss the PBoC’s monetary tools at length in Chapter 10.

Chapter 6: Real Estate and Exports Drive Industrial Production

We now turn to the production part of the business cycle. As Figure 6-1 shows, two factors affect China’s industrial output: real estate investment and exports. These two indicators represent domestic demand and international demand, respectively. Let’s start with the domestic side.

As discussed in the previous chapter, real estate companies build properties on their land, they hire construction companies and buy industrial goods, such as cement, concrete and steel. When the demand for industrial goods goes up, so does production. Nominal production or nominal GDP is the most important indicator for measuring macroeconomic conditions and is the key driver of interest rates. So, we must make a judgment about the production before predicting interest rates.

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| **Figure 6-1** |
| **Real Estate Investment and Exports Drive Industrial Production** |
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The full terminology of investment in China is fixed asset investment. Readers may wonder why real estate investment, of all the investment categories, is the most critical. In most industries, investment means purchasing or building plants and machines that produce industrial goods for companies to sell. If the market demand for industrial goods goes up, companies expand their production. When production reaches its capacity limit, companies invest in fixed assets to boost their production capacity. Thus, in most industries, sales growth does not necessarily lead to investment growth if the capacity utilization rate is low. In manufacturing industries, companies sell industrial goods instead of fixed assets. But in real estate, what is being sold is the investment itself. The construction of a property is an investment in real estate, and the property will be sold or rented (less often) once it is finished. While most industries invest in fixed assets and sell goods, the real estate industry both invests in and sells fixed assets. And because real estate investment is closely related to industrial production, the real estate cycle became the critical driver of macroeconomic cycles. Though other investments also affect industrial production, only the real estate investment shows a clear cyclical pattern and is large enough to drive the macroeconomic trend.

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| **Figure 6-2** |
| **Schematic Diagram: Real Estate Investment and Industrial Production**    **Industrial production is in nominal value. As real estate investment picks up steam, companies need to buy more industrial goods such as steel, concrete, glass, etc. A rise in real estate investment drives up nominal industrial production.** |
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Figure 6-2 shows the schematic diagram of real estate investment and industrial production. I want to stress again that it is the nominal economic variable that moves the bond market. Price plays a vital role in rates analysis. Thus, everything we are studying, including industrial production, is in nominal value.

One of the most important economic indicators made by the National Bureau of Statistics is the industrial production, or industrial added value. This indicator is released around the 17th of every month. It is recorded in real values and measures the real industrial output made by above-designated-size companies. There is no nominal indicator for industrial production in China, so we need to be creative. An excellent method to reinstate price is to add the year-over-year change of Purchasing Price Index (PPI) because PPI measures the change in prices of industrial goods. Combining PPI and industrial production gives us a convenient measurement of nominal industrial output. Now when we look at Figure 6-3, we shall see that real estate investment leads nominal industrial production for zero to three months.

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| **Figure 6-3** |
| **Real Estate Investment Leads Nominal Industrial Production for a Very Short Period of Time**  Source: Wind Database |
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We could also chart nominal industrial production with construction and installation investment. Comparing Figure 6-3 and Figure 6-4, we can see that the causal relationship between real estate investment and nominal industrial production was more robust with total real estate investment after 2011, and stronger with construction and installation investment before 2011. There isn’t a good explanation for this, so my suggestion is to look at both charts when making forecasts.

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| **Figure 6-4** |
| **Construction and Installation Costs Lead Nominal Industrial Production for Zero to Three Months**  Source: Wind Database |
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Nominal industrial production surged in 2016 and 2017, and thus created some anomalies in many charts and models. The surge was the byproduct of the Supply-Side Reform. In 2016, the Vice Premier Liu He, a Harvard-educated economist, led the Supply-Side Reform. The reform significantly pushed up PPI and led to a surge in nominal industrial production, while the real industrial production decreased during this time.

Supply-Side Reform was carried out by the administration to tackle severe industrial overcapacity problems. Years of loosening monetary policy reduced borrowing costs for big state-owned enterprises (SOE), especially in heavy polluting industries. As SOEs borrowed billions and billions with outrageously low interest rates to massively expand production in coal, steel, wires and many other low-profit and low-end industrial goods, the industrial prices were twisted to the historically lowest level, which hurt industrial profits. In a market economy, companies would start to reduce capacity and lay off workers to pump up profits, but since these industries were dominated by SOEs, market clearance became impossible. SOEs have a social responsibility to keep the job market stable, and massive layoffs are out of the question without the government’s consent. Executives of SOEs are also politicians, whose careers could be jeopardized if they are accused of damaging thousands of people’s livelihood. Without incentives for companies to reduce capacity, the government had to intervene. Vice Premier Liu He led the efforts. The so-called Supply-Side Reform was named after his policy of issuing executive orders to reduce industrial goods’ supply and force outdated ‘zombie’ companies to go bankrupt. By limiting supply, the government pushed up industrial goods’ prices and improved profitability for the companies that survived the reform. The reform was very successful. In 2018, both the energy and steel sectors’ profits picked up, and the industries started to regain capacity.

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| **Figure 6-5** |
| **Nominal Industrial Production Moves Synchronously with Industrial Enterprise Profits**  Source: Wind Database |
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Except for events like the Supply-Side Reform, nominal industrial production should theoretically coincide with industrial enterprises’ revenue because revenue equals sales multiplied by price. The growth rate of industrial enterprises’ revenue is thus equal to the sum of price’s growth rate and real production’s growth rate. Unfortunately, data of industrial revenue was suspended in 2017, so instead of revenue, we use profit, assuming the volatility in profit margin is not large enough to invalidate the equation. As shown in Figure 6-5, nominal industrial production and industrial profits change in unison more or less. Some anomalies exist, partially because of accounting issues. The accounting standard in China is less rigorous compared to the US. Some volatility in industrial profit growth rate can be attributed to discrepancies in financial reports.

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| **Figure 6-6** |
| **Schematic Diagram: Export and Industrial Production**    **Manufacturers tend to keep a low level of inventory for export orders. Factories started to produce right after they receive orders from abroad. Thus, exports only slightly lead industrial production.** |
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Export also has a significant effect on industrial production, especially in recent years as the government has rolled out policies to prevent the real estate industry from overheating. Figure 6-6 presents the schematic diagram of export and industrial production. Export delivery value shows a strong correlation with nominal industrial production (Figure 6-7). Export is less important than real estate because it is not a leading indicator for production.

We have shown that real estate sales lead real estate investment, which coincides with nominal production. The long chain of real estate makes it a good leading indicator. But it is hard to predict the trend of nominal industrial production with export data. Export is driven by foreign demand, which cannot be directly observed.

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| **Figure 6-7** |
| **Export Delivery Value Coincides with Nominal Industrial Production**  Source: Wind Database |
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Methods for predicting industrial output, inventory and exports are discussed in Chapter 13.

Chapter 7: Industrial Production, Investment and Consumption

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| **Figure 7-1** |
| **Companies Invest to Expand Capacity if Demand Goes Up** |
| |  | | --- | |  | | **Table 7-1** | | **Constitution of Fixed Asset Investment**   |  |  |  | | --- | --- | --- | | **Category** | **Constitution** | **Proportion** | | Real Estate Investment | Real Estate | ~25% | | Manufacturing investment | Mining, Manufacturing | ~35% | | Infrastructure Investment | Electricity, Gas, Water Supply, Transportation, Warehousing, Postal Service, Environmental Management, Public Facilities | ~25% | | Other Investment | Finance, Education, Culture, Sports, etc. | ~15% |   Source: Wind Database | |  | |

As with the US economy, industrial production also leads manufacturing investment (Figure 7-1) in China. But I am less confident about the relationship between consumption and production because there are some blanks in the data regarding this part of China’s economic cycles.

As companies increase production to cater to increasing market demand, they may reach their capacity limits and thus need to invest in plants, factories and machines to expand their production capacity. Investing in fixed assets is a big commitment, and business owners only do so when they have confidence in the economy. Thus, the lag between profit surge and investment surge is usually longer than nine months (Figure 7-2).

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| **Figure 7-2** |
| **Schematic Diagram: Industrial Production and Manufacturing Investment**    **An uptrend in industrial production often leads to an increase in manufacturing investment. As companies increase their production, they will at some point reach their capacity and need to invest more in fixed assets, such as land, factories, assembly lines, etc.** |
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There are over twenty industry investments that can be broken down into four major categories: real estate investment, manufacturing investment, infrastructure investment and other investment. A detailed break down of the four categories is presented in Table 7-1.

As we discussed in Chapter 6, real estate investment is the primary driver of the economy. What the real estate industry sells is the invested fixed asset. Unlike most other industries in which the invested fixed assets can be repeatedly used to produce industrial goods, real estate industry’s invested fixed assets are sold immediately once finished. Thus, real estate companies must make investments all the time, and that drives economic growth.

Infrastructure investment is considered a stabilizer because the government increases infrastructure investment when economic prospects are weak and vice versa.

Manufacturing investment lies somewhere in between. It is not as volatile and important as real estate investment, but it is still a market-driven force that shapes the economy. For investment analysts, real estate investment is more important because it tells us where the economy is going in the next six to ten months. But manufacturing investment marks the future of the nation. Unlike the one-off real estate investment, manufacturing investment creates profits and cash flows for many years to come. A strong manufacturing investment now is a promise of industrial stability in the future.

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**Production Drives Manufacturing Investment**

Figure 7-2 shows how industrial production drives manufacturing investment. When demand keeps rising, companies increase their production. At some point, companies reach their limit of production capacity. In order to expand production capacity, they will increase their investment in fixed assets. Fixed assets are long-term tangible pieces of properties, facilities and equipment that are used in the companies’ operations to generate production. For example, suppose a local electric automobile producer owns five factories, and each can produce 50 electric cars per year. In most years, sales remain at about 200 to 250 cars a year. The city council passes an environmental protection package to provide subsidies for people who choose to buy an electric car instead of a gas-fueled car. As a result, the company will need to increase its production to over 350 cars per year to meet the growing demand for electric cars. The current production capacity is 250 cars (50\*5) per year. Thus, the firm invests in another two factories to expand its capacity and meet demand.

There are two prerequisites for increasing manufacturing investment: a rise in industrial profits and high capacity utilization rate. Companies are motivated to increase production only if they are confident about rise in profits. And the high capacity utilization rate makes it necessary to invest in new facilities to expand production capacity.

Figure 7-3 presents the historical dynamics between industrial production and manufacturing investment. Generally speaking, nominal industrial production or industrial enterprise profit leads manufacturing investment for three to four quarters in China. Profit is the primary source of manufacturers’ funding for investment. International experience shows that industrial profits’ growth rate has a clear procyclicality and leads the manufacturing investment’s growth rate by one to four quarters. As we discussed earlier, I use the sum of industrial production growth and PPI growth as a proxy for industrial profits growth. Obviously, in a period of economic prosperity and higher capacity utilization, corporate profits will improve, in turn supporting investment. The manufacturing industry will enter a reverse cycle during an economic recession.

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| **Figure 7-3** |
| **Industrial Production Leads Manufacturing Investment for Three to Four Quarters**  Source: Wind Database |
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From Figure 7-3, although nominal industrial production growth is ahead of manufacturing investment growth, the time lag in inflection point is generally longer and slightly less regular. For example, the surge in nominal industrial production in 2016 did not drive up manufacturing investment. This was because the Supply-Side Reform limited the investment in many manufacturing industries. The limit was lifted in 2018 when the reform was completed, but then came the Sino-US trade war. The trade dispute interrupted the normal business cycle and suspended a lot of investment — likely until the situation is resolved or the direction becomes clearer.

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**Industrial Profits Drive Employment and Personal Income**

Now comes the painful part of the framework: the relationship between personal income and production. The lack of quality data creates some difficulty for this part of the analysis. There are a few quarterly and annual data that are related to personal income, but low-frequency data barely helps investment analysts.

As companies’ profits increase, they tend to hire more people and give their employees higher salaries. We see from Figure 7-4 that nominal industrial production leads PMI Employment, which is the Purchasing Manager Index that measures month-over-month change of employment conditions.

We don’t know how industrial profits affect household income because we lack the data on personal income, nor do we know how income and employment boosts lead to higher consumption. We can only make the inference based on economic logic.

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| **Figure 7-4** |
| **Industrial Profit Leads Employment**  Horizontal dash-and-dot line indicates the 50% cut-off of PMI.  Source: Wind Database |
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**Consumption Drives Production, in a Way**

China’s economy is not yet driven by consumption. Nonetheless, we can see that consumption has some effect on production (Figure 7-5). In previous chapters, we established that production is mostly driven by real estate investment and export. In recent years, China’s policymakers have been trying to reform the economy to encourage domestic consumption, only to see declines in the growth rate of consumption. The savings ratio (savings/total income) is still high, and China is one of the highest saving countries. As a result, China’s capital account surplus lowered the interest rates of developed markets, mostly the US. Chinese investors have been pouring billions of dollars into the US treasury bond market, instead of into China’s consumer goods.

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| **Figure 7-5** |
| **Consumption Has Some Effect on Industrial Production**  Source: Wind Database |
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We have shown that nominal industrial production coincides with industrial enterprises’ profits. One can use either to measure how the manufacturing business is faring. I recommend using nominal industrial production for two reasons. First, nominal industrial output is more reliable than industrial enterprise profits because inadequate accounting regulations might interfere with profit measurement. Secondly, data on industrial production and PPI is released sooner than that of industrial enterprise profits every month.

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| **Figure 7-6** |
| **Automobile Consumption Accounts for over 10% of Total Consumption**  Data obtained in Dec 2019  Source: Wind Database |
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A better way to study consumption is to follow automobile sales. Notice that automobile consumption accounts for over ten percent of total social consumption (Figure 7-6). It is worth studying the automobile consumption data because it has the largest monetary value per transaction compared to all other consumption categories. Also, many people borrow car loans when they buy cars; thus, automobile consumption can affect financing activities and contribute to M1. The National Bureau of Statistics didn’t record automobile consumption until 2019, but fortunately the China Passenger Car Association has been publishing automobile sales data since 2008. Figure 7-7 plots automobile sales growth with M1 growth, and we can see a clear coincidental relationship. Automobile sales have become progressively important in recent years as consumption’s contribution

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| **Figure 7-7** |
| **Automobile Sales Also Contribute to M1 Growth**  Source: Wind Database |
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| **Figure 7-8** |
| **Automobile Sales Lead Nominal Industrial Production**  Source: Wind Database |
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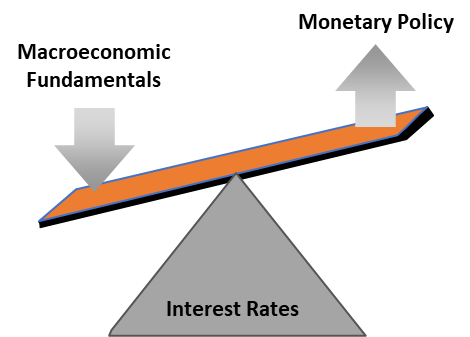
to GDP increases.

We can use automobile sales data to analyze the relationship between consumption and production. Although overall consumption has only a moderate effect on production, automobile consumption is a strong leading indicator of nominal industrial production (Figure 7-8). There so many categories of consumption, most of which are in small amounts, that changes in various categories of consumptions offset each other. By singling out automobile consumption, we can see more clearly whether people are increasing their spending.

Part 3: From Macroeconomics to Interest Rates

Chapter 8: Production, Inventory and Long-Term Rates

Both monetary policy and economic condition affect interest rates. The longer the investment horizon, the more important economic fundamentals become. The macroeconomic fundamentals lay the mid-to-long term trend for interest rates, and the central bank uses monetary policy tools to adjust interest rate fluctuations around the trend. Central bank adjusts, rather than control, the interest rate movements because bending a macroeconomic trend would be impossible even for the most powerful central bank. From my experience, I believe it is the macroeconomic fundamentals that decide the direction of interest rate movements and the monetary policy that decides the amplitude of interest rate movements.



To measure economic condition on a monthly basis, many macro analysts who cover China rates strategy pay great attention to the inventory cycle. Inventory is widely considered a coincidental indicator for long-term interest rates in China. Analysts like to keep track of inventory cycle and even follow the detailed sector data on inventory. More experienced analysts have found that a few industries’ inventory cycles lead the rest. For example, the automotive industry’s inventory is often considered a leading indicator for the overall inventory cycle. Keeping track of so many industries’ inventory data creates a heavy workload. I understand that most analysts see inventory as a proxy indicator for the general economic condition — the theory has some merits since long-term interest rate and inventory do often move coincidentally — but as we can see in Figure 8-1, there are long periods of discrepancies.

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| **Figure 8-1** |
| **Interest Rate Usually Moves Synchronously with Inventory Cycle, but Discrepancies Exist**  Source: Wind Database |
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Contrary to many China rates strategists, I’m not convinced that inventory cycle is a primary indicator for long-term interest rate movement. For instance, during the Covid-19 outbreak, inventory quickly rose to a historical high, but interest rates kept falling. I believe nominal industrial production plays a bigger role in driving interest rates, and inventory is in fact the byproduct of the production cycle. Analysts tend to overlook nominal industrial production because China only discloses data on real industrial production, and most analysts neglect the need to adjust real industrial production with PPI to derive nominal industrial production.

Figure 8-2 proves that it is the nominal industrial production rather than inventory that drives interest rate movements. There appears to be only one short period of anomaly in 2016, which was a time of upheaval for bond investors because the central bank maintained an extremely relaxed monetary policy. Banks borrowed from each other and created enormous amounts of money with shadow banking. Interest rates were lowered by both the central bank and commercial banks. Except for this short period of time, nominal industrial production moves in the same direction as long-term interest rate.

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| **Figure 8-2** |
| **Nominal Production Is the Key Driver of Interest Rate Movement**  Source: Wind Database |
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If an analyst fails to use industrial production and PPI to calculate nominal production, he could be easily lured into using inventory as an indicator for the economic fundamentals.

In spite of my distrust of inventory as interest rate’s coincidental indicator, it is still worth studying the inventory cycle. Let’s start by dividing an inventory cycle into four stages, as shown in Figure 8-3. An inventory cycle can be broken into four states: passive destocking, active replenishment, passive replenishment and active destocking. In the passive destocking stage, sales go up, but companies are not quick enough to increase their production, and they have to sell a larger portion of their inventory to satisfy the growing market demand. In the active replenishment stage, sales have been increasing for some time and companies realize that demand is picking up. In response, they increase their inventory to prepare for growing demand in the future. In the passive replenishment state, market demand starts to decline while production remains high, and a larger portion of the output becomes inventory. Finally, in the active destocking stage, companies have noticed the declining demand and start to reduce their production to a level of destocking inventory in order to cut costs.

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| **Figure 8-3** |
| **Four Stages of the Inventory Cycle** |
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| **Figure 8-4** |
| **Calculate Demand from Production and Inventory** |
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The rotation of the four stages explains why interest rate sometimes doesn’t move synchronously with the inventory cycle. Interest rates rise when the macroeconomic condition improves, and interest rates fall when the economy worsens. But a rise and fall in inventory doesn’t necessarily indicate an improving or deteriorating macroeconomic condition. The passive destocking stage indicates economic improvement as companies are making more money from growing sales; while the passive replenishment indicates economic deterioration as it becomes increasingly difficult for companies to sell newly produced goods. In short, it is the demand/sales rather than inventory that determines the condition of the economy.

We can use production and inventory to construct a demand index. Demand is higher when a larger portion of the output becomes sales instead of inventory, and demand is lower if a larger portion output can’t be sold and has to go into the stock as inventory. This principal is illustrated in Figure 8-4. Thus, I constructed the growth rate of demand with the following equation:

Demand growth = Industrial production growth + Industrial inflation (PPI) growth – Inventory growth

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| **Figure 8-5** |
| **Demand Leads Production**  Source: Wind Database |
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Intuitively speaking, demand is the fundamental driver of all economies, and theoretically, companies will adjust their production plans in response to changes in the market demand. If this hypothesis holds, then demand should lead industrial production. Figure 8-5 supports this hypothesis.

As demand surges, companies prepare for production expansion and increase their borrowing. As we have discussed earlier, M1 measures the amount of borrowing that is closely related to business activities. Therefore, demand is likely to coincide with or slightly lead M1 (Figure 8-6). The coincidental relationship between demand and M1 gives us the confidence about the legitimacy of the way we constructed the demand indicator.

Interestingly, I found that the demand growth also has some effect on long-term interest rate. As we can see in Figure 8-7, the yield-to-maturity of 10Y treasury bond tends to rise when the demand growth rate is positive and tends to fall when demand shrinks. Demand’s fluctuation shows a clear cyclical pattern, which makes it possible to observe the long-term trend and estimate the next inflection point in interest rates.

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| **Figure 8-6** |
| **Demand Coincides with M1**  Source: Wind Database |
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| **Figure 8-7** |
| **Rising Interest Rate Appears with Positive Demand Growth**  Vertical dash-and-dot lines indicate the zero points of the demand growth  Source: Wind Database |
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Generally speaking, macroeconomic fundamentals have a stronger effect on long-term interest rates, e.g., 10Y treasury bond’s yield-to-maturity. On some level, the central bank and the Ministry of Finance can influence the short-term changes in the long-term rates by controlling the supply of money and treasury bonds, but the influence seldom lasts for more than two months. If the Ministry of Finance increased treasury bond issuance, then the money market would feel the tightening in liquidity and corporates would postpone bond issuance plans to avoid borrowing at high costs. Monetary authorities have stronger influence on short-term rates because short-term rates are directly related to interest rates of money market instruments, which the monetary authorities can easily manipulate. We will discuss short-term rates in the next chapter.

Chapter 9: Inflation, Credit Expansion and Short-Term Rates

In this chapter, we discuss the drivers of short-term rates, which are represented by 1Y treasury bond YTM or 3Y treasury bond YTM. A major difference between short-term interest rate and long-term interest rate is that the short-term interest rate can be manipulated by the monetary authority, while the long-term interest rate is mostly determined by the economic fundamentals. By changing the money supply, the central bank could exert influence on the money market. And because money market instruments’ duration and maturity are closer to short-term treasury bonds, the money market borrowing rates can affect the short-term interest rates. Therefore, it is necessary to include the central bank’s behavior in the short-term interest rate analysis.

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| **Figure 9-1** |
| **Before 2012, Short-Term Interest Rate Moved in Accordance with Inflation**  Source: Wind Database |
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Figure 9-1 shows that before 2012, the People’s Bank of China focused its monetary policy mostly on fighting inflation. The relationship between short-term interest rate and inflation has been discussed extensively in economic textbooks. On the one hand, bond investors ask for a return higher than inflation rate. When inflation goes higher, bond investors sell bonds and switch to assets with higher returns. On the other hand, the central bank often steps in when inflation rate keeps increasing. To maintain stable prices and prevent the economy from overheating, the central bank raises short-term interest rates with its open market operations (OMO) to discourage short-term borrowing and reduce money supply.

After 2012, however, short-term interest rate somewhat decoupled from the inflation rate. Inflation had been moderate since 2012, until the swine flu wiped out a significant portion of the country’s pork supply and pushed up the pork price in the second half of 2019. Short-term interest rate was much more volatile than inflation rate between 2012 and 2019. It is possible that the People’s Bank of China shifted its focus from inflation control to something else. I believe the new factor that the PBoC included in its decision framework is the systematic risk in the financial industry.

After the international financial crisis in 2008, the regulatory authorities of various countries recognized that to amend the old monetary policy framework and micro-prudential regulation, it was necessary to establish and strengthen a macro-prudential regulatory framework. The United States and the European Union successively announced the establishment of a macro-prudential supervision system and related specialized agencies in 2009. Other economies and international organizations followed suit by strengthening financial regulatory reforms. The People’s Bank of China also announced the introduction of macro-prudential assessment in 2010.

The macro-prudential assessment (MPA) made a major change to the traditional regulatory framework. MPA expanded the concept of credit and strengthened the supervision of bank assets. Bank assets account for the bulk of the total amount of assets in the financial market. And over the years, regulators have found that all those financing methods that increased leverage and weakened regulatory power are more or less related to banks.

The PBoC expanded the concept of credit, which in the past mostly meant loans, and proposed the concept of ‘broad credit’ to include bond investment, equity investments, repurchase agreements, etc. The new approach allows authorities to regulate banks when they use these channels to bypass tradition loans to increase leverage.

Loans differ from other financial assets on banks’ balance sheets. As explained in Chapter 5, the banking system have the ability to create money, and the required rate of deposit reserve is the limit of that ability. Commercial banks’ balance sheet grows faster by issuing loans than investing in bonds. For example, suppose a bank enters a repurchase agreement with the central bank and borrows ten million dollars. If the required rate of deposit reserve is ten percent, then the bank can use that money to issue loans or buy newly issued bonds of a hundred million dollars at maximum. In this scenario, the bank’s balance sheet increases by 110 million dollars (one hundred from loans and ten from repo). But if the bank uses that money to invest in financial instruments that already exist, it can only expand its balance sheet by ten million dollars because it doesn’t create new credit in the monetary system. This example shows that a bank’s balance sheet grows slower if it chooses secondary market security investments over loans.

From the standpoint of the PBoC, since China’s direct financing is still immature and loans are the primary source of funds for business, PBoC tends to encourage banks to use funds to issue loans instead of making risky investments in the secondary market. If the bank’s balance sheet grows too slowly, the PBoC would suspect that the bank is not issuing enough loans to help the real economy but instead leveraging up within the financial system. The PBoC would then raise the short-term interest rate to discourage banks from using leverage to ‘make money from money.’ On the other hand, when the real economy has trouble obtaining funds, the PBoC lowers the short-term interest rate and encourages the banks to lend to small and medium businesses. In this scenario, banks are issuing more loans, and their balance sheets grow faster.

One way to measure the growth of banks’ balance sheet is to compare it with the growth of the central bank’s balance sheet. If the growth rate of commercial banks’ assets exceeds the growth rate of the central bank’s assets by a sizeable amount, then the economy is in a stage of credit expansion. Credit expansion is often coordinated by the PBoC to ensure not only that the market has enough liquidity to issue loans but also that companies can borrow at an affordable cost. As is shown in Figure 9-2, since 2012, a greater gap in the asset growth rate between the commercial banks and the central bank is often accompanied by declining short-term rate.

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| **Figure 9-2** |
| **After 2012, Central Bank Also Takes into Account the Financial Cycle to Influence Short-Term Interest Rate**  Source: Wind Database |
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Looking beyond, I believe that both inflation and credit expansion will influence the PBoC’s monetary policy. How do we decide when the PBoC cares more about inflation or more about credit expansion? The answer is unclear. Monetary authority’s decision process is not meant to be guessed by the public; otherwise, any monetary policy would be ineffectual since the market price of assets would reflect in advance the potential moves made by PBoC. Economically speaking, I think it is reasonable to assume that the PBoC will put more weight on credit expansion when the economy is worsening and on inflation when the economy is booming.

Chapter 10: Monetary Policies and Money Market

In this chapter, I will introduce the central bank’s monetary policy instruments. The central bank’s monetary policy has a significant effect on the money market and could greatly affect the short-term borrowing costs of financial institutions. The People’s Bank of China enumerates eight monetary policy tools on its official website (Table 10-1).

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| **Table 10-1** |
| **The Eight Tools in PBoC’s War Chest**   |  |  | | --- | --- | | **Name** | **Importance** | | Open Market Operations | ⭐⭐⭐ | | Required Reserves | ⭐⭐⭐ | | Central Bank Loans | ⭐ | | Interest Rate Policies | ⭐ | | Loan Prime Rate (LPR) | ⭐⭐ | | Standing Lending Facility (SLF) | ⭐ | | Medium-Term Lending Facility (MLF) | ⭐⭐⭐ | | Pledged Supplementary Lending (PSL) | ⭐ |   Source: The People’s Bank of China |

Tracing back the history, we can see that these monetary policy tools were not always part of PBoC’s operating policy; rather, they were developed gradually alongside the financial market’s evolution. Let’s go through the history of monetary policy tools.

In early days of the People’s Republic of China, the government imposed a command economy. There was only one bank in the whole country, the People’s Bank of China. At that time, deposits and loans were centralized to PBoC. Deposits received at branch banks at all levels were handed over to the head office, and loans were then approved by the head office according to project applications nationwide. The PBoC acted more like an accountant instead of a bank during this period. And in 1969, the State Council even made the astonishing decision to merge the PBoC and the Ministry of Finance. In a command economy, resources are allocated mostly according to fiscal decisions, so there wasn’t any true monetary policy per se.

Then, in 1978, The Third Plenary Session of the Eleventh Central Committee of the Communist Party decided that China should ‘open up and reform.’ PBoC was once again separated from the Ministry of Finance. Also, to break PBoC’s monopoly on the banking industry, the government established three other banks: Bank of China, Agricultural Bank of China, and China Construction Bank. These three banks began to operate as real commercial banks, while the PBoC took over some of the regulation and macro-control responsibilities from the Ministry of Finance. As the market looked to PBoC for the central bank’s responsibilities, the three major banks were largely uncooperative because they were of the same administrative level as the PBoC, and their CEOs answered only to the State Council. To solve this problem, the State Council enacted a law that formally established PBoC as the central bank of China in1983.

After becoming the official central bank, PBoC immediately rolled out two monetary policy tools: the central bank loan and interest rate policy.

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**Central Bank Loan**

Initially, there were two kinds of central bank loan: relending and rediscount. When the economy was bad, authorities wanted companies to increase their borrowing from banks and spend the money on manufacturing. If commercial banks fell short in liquidity, the PBoC would lend money to the commercial banks, increasing M0 and providing the cash needed. From 1985 to 1994, central bank lending accounted for over seventy percent of M0 growth. When the economy was overheated, PBoC reduced its lending to commercial banks to discourage companies from excessive borrowing.

Rediscount loans were much like today’s banker’s acceptance business. For example, suppose two companies make a trade. Company A buys twenty tractors from company B. Instead of paying cash to company B, company A writes company B an IOU, which promises the cash payment in six months. Company B could hold on to the IOU and wait six months, or it could sell the IOU to a bank at a discount. Such activity happens everywhere at any given time, and banks often hold multiple IOUs. If a bank finds itself short of liquidity, it could sell the IOUs it holds to the PBoC. That is the definition of a central bank rediscount — when a commercial bank sells its IOU to the central bank.

Rediscount worked like loans at the beginning. It was strictly limited to the agricultural and infrastructure industries, which were considered strategic at the time. In 1994, three policy banks were established, and they took over the responsibilities of supporting strategic industries from PBoC. Since then, rediscount became a real and effective monetary policy tool.

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**Interest Rate Policy**

The central bank can adjust interest rate to encourage consumption or cool down production. One way to control market rates was to adjust the interest rates on central bank loans. Another was to adjust the benchmark interest rate. China used to set limits on interest rates on loans and deposits. For example, the central bank could publish a benchmark rate and require that all loans’ interest rates must be lower than the benchmark interest rate plus 20bps.

This policy was opposed by almost everyone. Banks blamed the PBoC when the benchmark rate was high and banks had to borrow at high costs. They also complained when loans’ rates were low and hurt banks’ profits. The interest rate policy was in opposition to market reform, and it was difficult to implement. From the central bank’s perspective, it couldn’t allow interest rates to be marketized because it feared that banks, in order to seize market shares, might attract deposits with irrationally high interest rates while lending at low rates. It was not until the deposit insurance system was established in 2015 that the central bank finally scratched the upper limit of deposit rates.

During the 1990s, China underwent a period of economic clearing in both the real economy and the banking industry. Numerous companies went bankrupt, and millions of people lost their jobs. It turned out that banks had been lending to obsolete state-owned enterprises and accumulated a lot of bad loans on their balance sheets. Many banks were on the verge of collapse. As a result, PBoC found it impossible to directly control the banking industry with executive orders. With the help of international investment banks, the Chinese government restructured some of the largest domestic banks and stripped off the toxic assets to professional asset management companies that specialized in non-performing loans investment. After that, banks were granted the autonomy to operate as real commercial enterprises. They would be responsible for their own investment decisions and risk management. The PBoC, in response to the market reform of the banking sector, also switched to more marketized methods of regulation. After the Asian financial crisis in 1997, PBoC made its first change in monetary policy by reforming the required reserve policy and restoring open market operations.

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**Required Reserves**

The central bank sets a required reserve ratio (RRR) for all commercial banks in the country. For example, if the RRR is fifteen percent, then for every hundred dollars deposited at a bank, the bank must deposit fifteen dollars to its account at the PBoC.

Generally speaking, when there are no major problems in economic fundamentals, the central bank adjusts the deposit reserve requirement mainly to hedge excessive liquidity or release a certain amount of liquidity. Historically, when the reserve ratio was intensively increased, it was generally to hedge excessive foreign exchange assets. However, when the economy fell, the reserve ratio increase could also be suspended. For example, during the 2008 financial crisis, although foreign exchange was at a high level, the reserve ratio was lowered.

China’s deposit reserve seemed to lack a kind of textbook proficiency. In theory, an increase in the deposit reserve requirement cuts the money multiplier and thus should have the decisive effect of monetary tightening. But China’s money market is not a closed system; it takes foreign cash into the system all the time because China is the largest exporter in the world. Therefore, even if the PBoC cuts the money multiplier, the market could still create enough money for business activities.

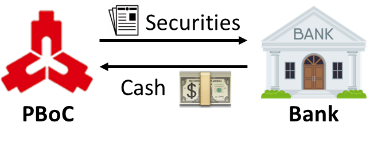
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**Open Market Operation**

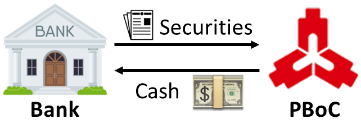
Open market essentially means the interbank market, as the PBoC had never touched a finger to any of the securities exchanges in China. Interbank market is the market where banks, brokers and money managers lend to and borrow from each other. The interbank market is extremely important as it is the primary source of liquidity. Numerous banks and money managers trade in this market, and interest rates are formed in the massive trading activities. The PBoC, the largest player in the market, can influence the money market interest rates by trading in huge volume in the interbank market.

When the interest rate in the money market is too high, sometimes even higher than the targets made by policymakers, the central bank can step in and buy assets from banks to insert cash into the market. Inversely, if the money market interest rate is too low, which means there is excessive liquidity, the central bank can sell assets to the market to absorb cash. This is the open market operation.

In 1998, the PBoC restarted its open market operation. The PBoC uses two kinds of open market operations: repo and reverse repo. In a repo trade, the PBoC sells a certain amount of securities, usually treasury bonds, to banks and promises to buy the securities back after a specified time, usually seven days to fourteen days. In this way, the PBoC reduces the cash flowing in the market. Repo trade is like a mortgage, in which the central bank borrows money from commercial banks and uses treasury bonds as collateral.



In a reverse repo trade, the central bank lend money to commercial banks and also ask for treasury bonds as collateral. In this way, the central bank injects money into the market.



Repos and reverse repos usually mature in 7, 14, 21, or 28 days. But occasionally, banks have extremely short liquidity needs. So, in 2013, the PBoC rolled out a shorter reverse repo instrument, the short-term liquidity operations (SLO), which has maturities ranging from one to six days.

Open market operations also have the function of interest rate guidance. The interest rate of repos and reverse repos is like the target rate made by FOMC. By adjusting the repo rate, the PBoC sends a message to the market about its monetary policy stands. If the PBoC lowers the repo rate, the bond market will rise.

In 2008, the subprime mortgage crisis broke out and threatened the global economy. China’s economy was very dependent on export at that time, and as the US and Europe lost their consumption momentum, China had to turn to domestic demands. A stimulus package of four trillion RMB helped China to make ends meet until 2012; by then the economy growth was once again touching the bottom line. In order to prepare for new risks and crises in the future, the PBoC rolled out a set of new monetary policy instruments: Standing Lending Facility (SLF), Medium-Term Lending Facility (MLF), and Pledged Supplementary Lending (PSL).

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**Standing Lending Facility (SLF)**

When the money market is extremely tight, banks might fail to finance their positions in securities. The standing lending facility lends banks emergency funds. SLF’s maturity is usually under three months — mostly overnight, seven days or one month. SLF is not a regular source of funds but more of a last resort for banks in serious solvency trouble. It is the counterpart to Federal Reserve Discount Window in the US. In extreme circumstances, SLF can effectively mitigate liquidity risks. In 2013, there was a period of extreme shortage of cash, and it was the SLF that provided emergency funds to the market.

A major difference between SLF and other monetary policy instruments is that it is the commercial banks instead of the central bank that decides when to use SLF. For most other instruments, such as central bank loans and open market operations, the central bank decides whether it wants to lend to banks. Therefore, any commercial bank would be very cautious about applying for SLF, because once it does, it would be on the central bank’s watch list, and the whole market will know that it is having solvency issues.

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**Medium-Term Lending Facility (MLF)**

Medium-term lending facility (MLF) is a loan from the central bank to commercial banks. MLF does not require collateral and has a much longer maturity compared to reverse repos. MLF has three types of maturities: three months, six months and one year. In recent years, the PBoC has discontinued issuing three- and six-month MLF. As of the time I wrote this book, all remaining MLF in the market have the maturity of one year. The terms of MLF look quite favorable to commercial banks, but there is a catch. Banks can only use the money borrowed from MLF to support small-and-medium enterprises and agricultural projects. The central bank created MLF to help businesses, and MLF should not be used to make risky financial investments.

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**Pledged Supplementary Lending (PSL)**

Pledged Supplementary Lending (PSL) is a special instrument designed specifically for shantytown renovation projects. In order to lift more people out of poverty and put them to work in urban cities, local governments moved people out of outdated and poorly constructed residential areas, tore down the old properties and built new apartments. And of course, the government needed to compensate people for the inconvenience and loss. To help local governments finance their projects and promote urbanization, the PBoC rolled out PSL in 2014 to monetize shantytown renovation projects. The PBoC first used PSL to lend money to policy banks, mostly to the China Development Bank; then, the policy banks lent the money to local governments so that they had the money to reimburse people who were forced out of their homes. Since renovation projects usually take many years to complete, the maturity of PSL was set to three to five years.

Finally, in 2019, the PBoC made another change to help businesses access cheaper loans. For too long, interest rates in the capital market were not correlated with interest rates on loans. All the instruments discussed above only helped to maintain the stability of the interbank money market and the bond market, but loan rates seldomly move synchronously with policy rates. Banks tend to only lend to large and state-owned enterprises because the risk is low, and they often neglect the companies that genuinely need the funds. While banks enjoy a stable bond market under the protection of the central bank, real economy businesses, especially small and medium enterprises, still struggle to get access to loans. To solve that problem, PBoC reformed the loan prime rate (LPR)

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**Loan Prime Rate (LPR)**

The loan prime rate (LPR) in China is the lending rate provided by commercial banks to their highest quality customers and serves as the benchmark for rates provided for other loans. Since 2019, eighteen commercial banks in China — including ten national banks, two municipal banks, two rural village banks, two privately owned banks and two foreign banks — report their desired rates to the central bank, and the LPR is calculated as the average of the sixteen offers, excluding the highest and lowest. The PBoC authorized the National Interbank Funding Center to serve as the designated publisher of the LPR. These eighteen banks are called ‘the panel banks.’

The new rule requires the panel banks to link their LPR quotations to the rate of medium-term lending facility (MLF). All banks are required to use the LPR as a reference to price new loans. So, the central bank can influence loan rates by influencing the rate of MLF.

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| **Figure 10-1** |
| **Spectrum of Monetary Policy Tools** |
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Figure 10-1 summarizes the spectrum of PBoC’s monetary policy war chest. These tools have significant effects on the money market and extend their influence to short-term interest rates through money market financing activities. PBoC also express its view of the macroeconomic conditions through monetary policies, and that sometimes creates emotional momentums among investors. Analyzing monetary policy is more important to day traders whose investment horizon is short. The PBoC issues monetary policy reports every quarter and it is important for analysts to read between the lines to guess what the officials from monetary authorities are thinking. This is particularly challenging for non-Chinese speakers, but fortunately many sell-side analysts are now publishing analytical reports in English. As China continues to open up its capital, PBoC will continue to make its policies more understandable to foreign investors as well.

Part 4: Forecasting Techniques

Chapter 11: Forecasting M1

To forecast the economy, we need a starting point. In the US, the starting point could be non-farm payroll. More jobs, more income. More income, more consumption. More consumption, more production, and so on. Everything starts with jobs. That’s why every month when the US non-farm payroll data is released, traders and analysts across the world stare at their screens and hold their breath. For China, as I have explained, that starting point is real estate sales and financing activities.

Predicting the starting point is difficult because it leads everything else and usually doesn’t have any leading indicator (otherwise we won’t call it the starting point). Nonetheless, sometimes the bond market temporarily moves in response to M1 rather than waiting for the actual hit in production or investment, and the stock market often responds to M1 shocks quite swiftly. So, it can be useful to explore possible ways to forecast financing activities and real estate sales. Specifically, this chapter aims to provide a method to forecast M1.

I found that paper financing can be used to predict M1 growth, as seen in Figure 11-1. Paper financing is the total banker’s acceptance bills accepted and discounted by commercial banks. A banker’s acceptance, or BA, is a negotiable instrument or time draft drawn on and accepted by a bank. Before acceptance, the draft is not an obligation of the bank; it is merely a promise by the drawer to the bank to pay a specified sum of money on a specified date to a named person or the bearer of the draft. Upon acceptance, which occurs when an authorized bank accepts and signs it, the draft becomes the primary and unconditional liability of the bank. The banks pay the bearer at a discount and collect the payment from the drawer on the specified date. If the bank has a good reputation, the accepted draft may be readily sold in an active market.

What is noteworthy in Figure 11-1 is the synchronism between the zero point of paper financing growth and the inflection point of M1 growth. This suggests that a link may exist between paper financing and M1.

Through my analysis, I developed a theory to explain this relationship between paper financing and M1. We have established that M1 moves with business borrowing. At the beginning of the M1 cycle, or credit cycle, commercial banks’ risk preference is low, so the banks tend to use low-risk loans to tap the water. At this early stage of credit expansion, banks issue more short-term loans and accept more banker’s acceptance bill. Thus, when a new credit cycle starts, growth rate of paper financing turns positive, and growth rate of M1 starts to go up. In the late stage of a credit cycle, banks have sensed the declining demand in the economy and start to cut back on credit issuance. In this stage, since the credit risk exposure has been high, banks would start with the least profitable debts, which are, again, short-term loans and banker’s acceptance bills. Thus, negative growth rate of paper financing indicates a decline in the growth rate of M1.

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| **Figure 11-1** |
| **Paper Financing and M1**  Vertical dash-and-dot lines indicate the zero points of paper financing growth, and we see a pattern that those vertical lines often pass through the inflection points of M1.  Source: Wind Database |
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Even though paper financing is a coincidental indicator for M1, it is still possible to use paper financing to predict the trend of M1 growth. The graph shows that paper financing follows an amazingly smooth pattern of cyclical fluctuation. Each cycle of paper financing has roughly the same length — around forty months — and its trend has always been clear. It is possible to use linear extrapolation to make a rough inference on the next zero point of paper financing growth and then use the expected zero point to predict the next inflection point of M1.

Forecasting M1 is hard, just as it is hard to forecast US non-farm payroll because these are the staring points of macroeconomic analysis. They are supposed to lead other economic indicators and are not meant to be accurately predicted. So, we should not expect to be able to always make good predictions on M1. Instead, we should treat M1 as the starting point of predicting other economic indicators.

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| **Figure 11-2** |
| **Linear Extrapolation of Paper Financing**  The slopes of the three declining cycles were almost identical, which makes it convenient to use linear extrapolation to estimate the next zero point.  From this graph we could estimate that the next inflection point of M1 would be in the third quarter of 2020. |
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Chapter 12: Forecasting Inflation

In this chapter, I’ll introduce a few ideas about forecasting inflation, specifically CPI and PPI. Both indicators are crucial to bond investors. CPI marks the lower barrier of bond yields as investors almost always ask for a return higher than CPI. And changes in PPI indicate changes in industrial demand and industrial enterprises’ profits, which are important in predicting long-term interest rates.

Let’s start with PPI. Four factors are known to predict PPI: real estate sales, M1, CRB index and RMB exchange rate. Among these four factors, real estate sales and M1 measure the domestic demand, while CRB index and RMB exchange rate measure international demand. Real estate and M1 have been discussed again and again in this book. As I often put it, real estate is the engine of China’s economy and M1 is the fuel. (This won’t be the last time I mention them!)

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| **Figure 12-1** |
| **Real Estate Sales Lead PPI for Five to Seven Months**  Source: Wind Database |
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Figure 12-1 shows that real estate sales lead PPI for about five to seven months. Higher sales in real state is a sign that the entire economy’s demand is picking up. And before producers can keep up with the pace of the growing demand, prices will rise first.

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| **Figure 12-2** |
| **M1 Leads PPI for Five to Seven Months**  Source: Wind Database |
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As we have seen earlier, M1 is a coincidental indicator of real estate sales. Figure 12-2 shows that M1 also leads PPI. Factors other than real estate sales can also affect M1; the fact that real estate sales moved almost entirely synchronously with M1 in the past two decades doesn’t guarantee that the relationship will hold in the future. It’s better that we use both as indicators for domestic demand.

From the perspective of the global supply chain, international commodities are the raw materials of domestic industrial goods; thus, commodity price affects PPI (see Figure 12-3). The Commodity Research Bureau (CRB) Index measures the aggregate price of global commodity markets. To maintain profit margin, manufacturers raise their prices when the global commodity market goes up.

Commodity trades are mostly settled in dollars and euros; analogously, the exchange rate of Renminbi, China’s currency, also leads PPI. Similar to the Dollar Index, Renminbi has its own index — the Real Effective Exchange Rate Index (REER Index) — as a measurement of exchange rate against a basket of foreign currencies. Strong Renminbi reduces the cost for commodity importers and thus reduces PPI. As shown in Figure 12-4, REER Index growth reversely leads PPI growth for about three to four months.

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| **Figure 12-3** |
| **Commodity Price Leads PPI for About a Quarter**  Source: Wind Database |
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Combining the four factors, I applied the error correction model (ECM) to derive quantitative forecasts of PPI. The model setting is similar to the iSwap Model, which was developed by Goldman Sachs to price inflation swap contracts. A detailed description of the error correction model is presented in Chapter 16.

Figure 12-5 shows the in-sample prediction. In May 2019, the model accurately predicted industrial goods deflation in the third quarter of 2019, months ahead of market expectation. In the first half of 2019, the economy outperformed expectation, and the market was optimistic about increasing demand. Only a few people were concerned about impending deflation. I alerted my department and we increased the duration of bond portfolio just before PPI growth went below zero.

Analysts who have taken intermediate level econometrics may also want to use autoregressive distributed lag (ADL) model for this one. I found ADL model helpful too, but the error correction model can capture the trend more effectively. Without the error term adjustment, ADL model’s prediction tends to fluctuate around the trend. Generally

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| **Figure 12-5** |
| **Four Factor Error Correction Model Predicts PPI for Three Months**  The model alerted industrial good deflation in 2019, three months ahead of market expectation. |
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| **Figure 12-4:** |
| **REER Index Reversely Leads PPI for About a Quarter**  REER Index Y/Y is reversely plotted  Source: Wind Database |
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speaking, use ECM if you want to predict the trend, and use ADL if you want to predict the value. I use dynamic factor model and Kalman Filter to predict the exact value of inflation indicators, which I’ll discuss later.

Forecasting CPI is a little trickier because China’s CPI is volatile. Food items account for a significant portion of the CPI basket, and food price is very hard to predict. There are many factors that need to be taken into consideration, such as previous-season harvests, weather, transportation costs, etc. Instead of bluntly predicting the CPI, we could divide CPI into two parts, Food CPI and Non-Food CPI, and tackle them separately.

As shown in Figure 12-6, Non-Food CPI is highly correlated with PPI. This is not surprising because the PPI basket overlaps with non-food items in the CPI basket. Notice that the correlation changed after 2011. Since 2011, Non-Food CPI becomes less sensitive to changes in PPI, but they still move in the same direction and have synchronous inflection points.

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| **Figure 12-6** |
| **PPI Is Positively Correlated with Non-Food CPI**  Source: Wind Database |
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When running regressions, we should divide the sample into pre-2011 and post-2011. Alternatively, we can estimate the following equation:

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| **Table 12-1** |
| **Regression Results for Non-Food CPI**   |  |  |  |  | | --- | --- | --- | --- | |  | **Estimation** | **Std. Error** | **p-value** | |  | 0.1065 | 0.037 | 0.005 | |  | 0.2374 | 0.007 | 0.000 | |  | 1.5773 | 0.045 | 0.000 | |  | -0.1111 | 0.009 | 0.000 |   p-value<0.05 indicates strong evidence that the regressor has a certain effect on the dependent variable. |
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| **Figure 12-7** |
| **In-Sample Prediction of Non-Food CPI** |
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where represents the Non-Food CPI, represents PPI, is a dummy variable and equal to 1 if and only if *t* > 2011, and is the error term. By adding the dummy variable , we can estimate the post-2011 effect. The regression results and in-sample prediction are shown in Table 12-1 and Figure 12-7 respectively. The in-sample prediction from the above equation is remarkably coherent.

Since we have established a methodology to predict PPI three months into the future, we can then use the predicted PPI and estimated equation above to predict non-food CPI.

The recipes of Chinese cuisines offer us a way to predict food CPI. The major source of protein consumption in China comes from pork; therefore, the National Bureau of Statistics puts a higher weight for pork in the CPI basket. And as we can see in Figure 12-8, the pork price drives the Food CPI. So, the problem is now converted to predicting the pork price.

Think about how pork is made. Reproductive sows are pregnant for nine to ten months before giving birth to piglets, and the farmers let the pigs grow for a few weeks before sending them to a butcher’s shop. It takes a sow about ten months to reproduce piglets. The more reproductive sows we have now, the more pork we will have in ten months, and therefore the lower the pork price will be in ten months. As shown in Figure 12-9, the growth rate of reproductive sows’ inventory reversely leads pork price growth for about ten months.

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| **Figure 12-8** |
| **Food CPI Is Driven by Pork Price**  Source: Wind Database |
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Now, we concluded the forecasting techniques for inflation. To sum up, we use real estate sales, M1, CRB Index and REER Index to predict PPI; we use reproductive sows’ inventory to predict pork price, which gives us the Food CPI; finally, we use the predicted PPI to forecast Non-Food CPI.

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| **Figure 12-9** |
| **Reproductive Sows’ Inventory Reversely Leads Pork Price for About Ten Months**  Data of reproductive sows’ inventory growth is in reverse order on the left axis  Source: Wind Database |
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Chapter 13: Forecasting Production, Inventory and Export

In this chapter, I will present some ideas on how to predict the three major indicators of macroeconomic condition: production, inventory and export. In my humble opinion, production and export are more important than inventory because these two indicators are more strongly correlated with the bond market. But inventory could confirm a trend indicated by production and export. Therefore, we will discuss the forecasting techniques for all three in this chapter.

This chapter is particularly important because we will see that the macroeconomic trend can indeed be predicted by leading indicators. If we can make an accurate forecast on industrial production, we can predict the bond market trend and get ahead of the curve.

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| Source: imgflip.com |
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**Predicting Nominal Industrial Production**

Predicting production is the most important step in forecasting the bond market. An upward trend of nominal industrial production growth almost always indicates rising interest rates, and a downward trend of nominal industrial production growth drives a bullish bond market. There are three indicators that can be used to predict nominal industrial production: M1, real estate sales and money multiplier.

Charting those three indicators against nominal industrial production is the easiest way to predict the long-term trend and inflection point of nominal industrial production. Figure 13-1, 13-2 and 13-3 show each of the three leading indicators can predict nominal industrial production relatively well.

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| **Figure 13-1** |
| **M1 Leads Nominal Industrial Production for Three Quarters**  Source: Wind Database |
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We have explained why real estate sales and M1 lead nominal industrial production, and we now add a third factor, money multiplier, into the equation. In economic theory, the money multiplier refers to the credit expansion multiple created by the process of generating money through the creation of the deposits within the commercial banks. The money multiplier is expressed in mathematical formula as:

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| **Figure 13-2** |
| **Real Estate Sales Lead Industrial Production for Three Quarters**  Source: Wind Database |
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The money supply can be expressed by either M1 or M2. The fluctuation of the money multiplier of M1 is relatively stable, and the trend is consistent with the money multiplier of M2.

The monetary base is the reserve currency of the central bank, which includes the currency issued (or printed) by the central bank and the deposit reserves of commercial banks in the central bank, that is: monetary base = currency issuance + required deposit reserve + excess deposit reserve.

The indication of changes in money multiplier is twofold. First, it reflects the monetary policy position of the central bank. Central bank can directly affect the money multiplier by changing the required reserve ratio. The central bank may lower the required reserve ratio and increase the money multiplier if it wants to support the economy more. A growth in the money multiplier helps companies gain loans and credits. Secondly, as I explained in Chapter 5, the creation of loans reflects the real economy’s demand. A surging multiplier indicates that the demand in the real economy is expanding fast. Thus, the money multiplier can reflect economic momentum. In Figure 13-3, we can see that money multiplier’s growth rate leads growth of nominal industrial production in the same way as estate sales and M1.

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| **Figure 13-3** |
| **Money Multiplier Leads Nominal Industrial Production for Three Quarters**  Source: Wind Database |
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All three indicators were picking up in 2012, so it was reasonable to predict an upward trend of nominal production in 2013. As we discussed earlier, nominal industrial production moves synchronously with interest rate. Thus, the overall prediction on bond market in 2013 would be bearish. Figure 13-4 confirms the accuracy of this forecast.

Similarly, both real estate sales and M1 were flattened in 2019, and there was no sign of inflection of the money multiplier. The downward trend stopped, but the charts showed no apparent evidence of bouncing up. This pattern indicates that in 2020, if the central bank holds still its monetary policy, the interest rate’s overall trend would be flattened at a low level. More experienced analysts would also predict that the interest rate’s volatility would increase in 2020 because that is usually what happens when interest rate stays low for a long period of time. But in this case, we need to adapt to unexpected shocks in the economy, the Covid-19 global pandemic. The pandemic turned a supposedly boring year for bond investors into a frenzy.

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| **Figure 13-4** |
| **Nominal Production Is the Key Driver of Interest Rate Movement**  Source: Wind Database |
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I didn’t build a model for this chapter, because charts are sufficient enough to predict long-term trends. Interested readers could utilize the various econometric tools to make more sophisticated forecasts. I recommend error correction model, autoregressive distributed lag model and, for more experienced statisticians, Markov-switching dynamic regression model.

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**Predicting Inventory**

I don’t quite believe in the idea of using inventory cycle to predict interest movements; nonetheless, I recommend also using real estate sales and M1 to predict the long-term trend of inventory. Even though inventory is not the key driver of interest rate movements, it is worthwhile to make some predictions about inventory as it could confirm the macroeconomic trend revealed by industrial production numbers. We would be more confident that the bond market is becoming bearish if both nominal industrial production and inventory go up.

A convenient method to forecast short-term trend of inventory is to use PPI. The logic is simple. When a producer senses that market demand is going up, he would want to increase inventory. But it takes time, usually weeks and months, to increase production capacity. Adjusting production requires ordering more raw materials, negotiating new contracts, hiring more people, renting more warehouses, etc. Econ 101 tells us that widening gap between demand and production increases the price. Before the producer could effectively increase production and his inventory, he would first raise the price. Thus, PPI leads inventory cycle.

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| **Figure 13-5** |
| **PPI Leads Inventory Cycle for About Four Months**  Source: Wind Database |
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Figure 13-5 demonstrates the relationship between PPI and inventory. If we are confident about an inflection point on the PPI curve, then the inflection of inventory is on its way.

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**Predicting Export**

To predict export growth, we can use the Purchasing Manager Index (PMI). PMI has many sub-indicators, among which the PMI New Export Orders can be helpful when making predictions about export growth. Each indicator of PMI reflects the reality of business activities, and the composite index reflects the overall growth or decline of manufacturing or service industries. The survey uses a non-quantitative questionnaire form. The respondent only needs to make a qualitative judgment on each question and choose one of three answers: up from last month, unchanged or down from last month. Then, the statistical authority counts the percentages of the three types of answers and translates the results into various indicators. The PMI and its sub-indicators are released on the last day of each month, which is ahead of the statistical reports of other government departments.

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| **Figure 13-6** |
| **PMI New Export Orders Leads Export Delivery Value for Four to Six Months**  Horizontal dash-and-dot line is the 50% cut-off point of PMI New Export Orders  Source: Wind Database |
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To make it more readable, I made Table 13-1 to show the five export trends in the past two decades and how PMI New Export Orders rose above or fell below fifty percent before exports reached its inflection points.

Another idea for predicting exports is to use the OECD Composite Leading Indicator (CLI). Especially, as shown in Figure 13-7, CLI for the G7 has a strong positive correlation with China’s export. The G7 are seven of the largest economies in the world: US, UK, Germany, France, Japan, Italy and Canada. They create a large proportion of global consumption and are among China’s top trading partners. The economic conditions of the G7 affect their import capabilities and, in turn, affect China’s export.

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| **Table 13-1** |
| **Historical Statistics on the Relationship between PMI New Export Order Index and Export Delivery Value**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Cycle** | **Year** | **First Month of PMI New Export Orders Expansion/Contraction** | **Export Inflection Point** | **Lead** | | Down | 2008 | Jul 2008 | Nov 2008 | 4 months | | Up | 2009 | May 2009 | Nov 2009 | 5 months | | Down | 2014 | Oct 2014 | Feb 2015 | 4 months | | Up | 2016 | Nov 2016 | Mar 2017 | 4 months | | Down | 2018 | Jun 2018 | Dec 2018 | 6 months | |
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| **Figure 13-7** |
| **G7’s OECD CLI Leads China’s Export Delivery Value**  Source: Wind Database |
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In this chapter, we discussed some techniques for forecasting the three major macroeconomic indicators: industrial production, export and inventory. Both nominal industrial production and inventory can be predicted by M1 and real estate sales, because real estate drives China’s overall domestic demand and M1 provides the funds for productions. Both indicators lead nominal industrial production for about three quarters. We can also use the money multiplier to predict nominal industrial production because growth in the money multiplier also indicates aggregate demand of the real economy. We can use purchasing manager index to predict export, which tends to coincide with production. Persistently low PMI (below 50%) indicates a downturn in export. Making accurate predictions about industrial production, export and inventory is the most important step in forecasting interest rate movements, as interest rate almost always moves synchronously with the macroeconomic trend.

Chapter 14: Tracking High-Frequency Data

We sometimes study data with a higher than monthly disclosure frequency to capture a turning point in the macroeconomic trend before it shows in the monthly data. The bond market has become increasingly sensitive to data and news. Sometimes the market also fluctuates on weekly data. This chapter provides a few high-frequency data series that are worth following. The most useful high-frequency data can be divided into three categories: production, demand and inflation.

Production-related data refers to the data that reveals how many industrial goods are being produced and how many factory plants are being used, e.g., the amount of steel produced in the past week, the capacity utilization rate of a large factory, the energy consumed by manufacturers, etc. Demand-related data refers to the amount of industrial goods consumed or transported, e.g., the weekly sales of cars, the amount of goods shipped to foreign countries, the floor space of commercial buildings sold, etc. Inflation-related data refers to prices of industrial goods, commodities and consumer goods.

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**Production-Related Data**

Let’s first take a look at the production-related high frequency data.

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| **Table 14-1: Production-Related High Frequency Data** |
| |  |  |  |  | | --- | --- | --- | --- | | Indicator | Unit | Frequency | Source | | Daily Average Coal Consumption by Six Major Power Generation Groups | 10,000 tons | Daily | www.cqcoal.com | | Operating Rate of Blast Furnace | % | Weekly | Wind | | Tangshan Steel Plant Capacity Utilization Rate | % | Weekly | Wind | | Automotive Tires Operating Rate | % | Daily | www.qinrex.cn |   Source: Wind Database |
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**Daily Average Coal Consumption by Six Major Power Generation Groups:** This data measures the daily average coal consumption of the six largest state-owned power corporations. Higher coal consumption indicates a higher level of business activities in the real economy. Both the manufacturing and service sectors consume electricity. Electricity cannot be stored in huge batteries, which means that the power industry does not have inventory. The power industry produces as much electricity as the real economy uses. Thus, the coal consumed by large power corporations is positively correlated to the level of business activities. Analysts often carefully follow this indicator because it leads long-term interest movements for a few weeks (Figure 10-1).

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| **Figure 10-1** |
| **Daily Average Coal Consumption by Six Major Power Generation Groups Leads Long-Term Interest Rate**  Both data are adjusted to weekly frequency by averaging  Source: Wind Database |
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**Operating Rate of Blast Furnace:** This data is calculated as number of blast furnaces in use divided by total number of blast furnaces nationwide. It measures the level of steel production activities.

**Tangshan Steel Plant Capacity Utilization Rate:** This data is calculated as capacity usage divided by total capacity of the Tangshan Steel Plant. It also measures the level of steel production activities. A higher capacity utilization rate indicates that the steel producers are putting a high portion of their plants to work, and thus we can expect higher steel production in the coming weeks.

**Automotive Tires Operating Rate:** This data is the operating rate of the automotive industry. It consists of two sub-categories, which are half-steel tire and full-steel tire. Similar to the operating rate of the steel industry, automotive tires operating rate measures the production activities in the automotive industry, which is downstream of the steel industry.

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**Demand-Related Data**

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| **Table 10-2** |
| **Demand-Related High Frequency Data**   |  |  |  |  | | --- | --- | --- | --- | | Indicator | Unit | Frequency | Source | | 30 Large and Medium-Sized Cities’ Traded Area of Commercial Buildings | 10,000 ㎡ | Daily | Wind | | Daily Average Sales of Passenger Car | unit | Daily | China Passenger Car Association | | China Cement Price Index | - | Daily | Ccement.com | | SCFI & CCFI | - | Weekly | Wind |   Source: Wind Database |
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Next, we examine demand-related high frequency data. In China, macroeconomists focus on four main indicators (Table 10-2).

**30 Large and Medium-Sized Cities’ Traded Area of Commercial Buildings:** This high-frequency data can be useful in predicting the monthly real estate sales. As shown in Figure 10-2, the growth rate of 30 Large and Medium-Sized Cities’ Traded Area of Commercial Buildings coincides with real estate sales. Thus, we can observe the daily trade data of the thirty cities to speculate the monthly sales data.

**China Cement Price Index:** Cement is mostly used in real estate and infrastructure constructions, making it a good indicator for construction activities. Cement price can fully reflect cement demand for two reasons. Firstly, cement cannot be stored. Cement will gradually harden after being damp. If the bagged cement is stored in a normal environment for three months, it should be regarded overdue. If the overdue cement is not hardened and is tested to meet various quality standards, it can only be used in lower intensity. It is strictly forbidden to use hardened cement in constructions. The storage time of bulk cement is shorter, generally no more than fifteen days. Therefore, the producers have only about one month of cement storage capacity. Secondly, the production process of cement is simple, and the switching cost is low, Glass, on the other hand, is difficult to stop once the production is started. In other words, cement prices are very responsive to changes in current demand, and rising price of cement basically means rising demand.

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| **Figure 10-2** |
| **30 Large and Medium-Sized Cities’ Traded Area of Commercial Buildings → Real Estate Sales**  Data of 30 Large and Medium-Sized Cities’ Traded Area of Commercial Buildings is monthly adjusted by aggregating  Source: Wind Database |
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**SCFI & CCFI:** China Containerized Freight Index (CCFI) and Shanghai Containerized Freight Index (SCFI) reflect China’s international trade activities. These two indicators were issued by the Shanghai Shipping Exchange (SSE) in 1998 and 2009 respectively. The difference between the two is that SCFI is more sensitive to short-term changes in exports because CCFI reflects the nationwide export container freight rates, including spot and forward price; whereas, SCFI reflects the export container freight rate of the active trading port of Shanghai and only includes the spot price. As shown in Figure 10-3, both indices can explain the trend of exports.

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| **Figure 10-3** |
| **CCFI & SCFI → Exports**  Data of CCFI and SCFI are monthly adjusted, export delivery value is on the right-hand side  Source: Wind Database |
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**Inflation-Related Data**

Lastly, we’ll discuss inflation-related high frequency data (Table 10-3).

**CRB Index:** We have discussed how we can use CRB Index to forecast PPI. The index is disclosed on a daily basis and it is worth to tracking its movement every few days.

**Average Wholesale Prices of Animals, Vegetables and Fruits**: These prices are extremely critical for estimating Consumer Price Index (CPI) in China. Food makes up about a half of China’s CPI item basket. Pork price is particularly important, as we have mentioned. There are over thirty categories of food prices, and we need to consider almost all of them to estimate monthly inflation level.

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| **Table 10-3** |
| **Inflation-Related High Frequency Data**   |  |  |  |  | | --- | --- | --- | --- | | Indicator | Unit | Frequency | Source | | CRB Index | - | Daily | Wind | | Average wholesale prices of animals, vegetables and fruits | CNY/kg | Daily | Ministry of Agriculture | | Nanhua Industrial Goods Price Index | - | Daily | Nanhua Futures | | WTI & Brent Oil Price | $/barrel | Daily | Wind |   Source: Wind Database |
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**Nanhua Industrial Goods Price Index**: This index measures the prices of domestic industrial goods. An upward trend in this index indicates higher level of industrial activities and industrial demands.

**WTI and Brent Oil Prices**: This index measures the prices of oil. The oil price not only reflects the current crude oil supply and current economic growth, but also reflects the market’s expectations of future supply and demand trends. This expectation determines the general direction of oil price and makes it a good indicator to assess the macroeconomic conditions in short term.

High-frequency data is becoming more and more important in research and decision-making for the following reasons.

First, we can use high-frequency data to observe changes in short-term economic operations as a basis to predict mid- and low-frequency data. This allow us to effectively capture the inflection points in mid- and low-frequency data series with greater certainty.

Second, mid- and low-frequency data is often published monthly and released in the middle of the next month. It is often not sensitive enough to market changes.

Lastly, low-frequency data is mostly published by government and interfered by non-market factors. It is an open secret that Chinese authorities often manipulate the monthly and quarterly data. Thus, including high-frequency data can make research and decision-making more accurate.

Part 5: Quantitative Methods

Chapter 15: Thoughts on Quantitative Models

Trained to be an applied mathematician, I found it useful and sometimes necessary to develop quantitative models in macroeconomic forecasts. Advanced knowledge in statistics, mathematical modeling and coding opens many doors for rates strategists.

My favorite model is the Nowcast Model, a combination of dynamic factor model and Kalman Filter. The Nowcast Model uses high-frequency data, e.g., the daily price of food items, to forecast low-frequency data, e.g., the monthly Consumer Price Index (CPI). It is called ‘nowcast’ rather than ‘forecast’ because it does not predict many time periods into the future. Instead, it estimates economic indicators a few days before they are released. I applied the model to use daily price data, which the relevant agencies release every day after working hours, to estimate the monthly CPI before the actual number of CPI is released in the second week of the next month. With the Nowcast Model, we can get a fairly accurate estimation of this month’s CPI at the end of this month — before the actual figure is released more than a week later. For example, if the market expectation of this month’s CPI is 2.5% while Nowcast gives us 1.2%, we can long the bond market a few days before the data is released and make a profit on the release day when rates fall in response to disappointing inflation level.

Nowcast is a powerful tool for traders, but only a handful of analysts know how to apply it to China’s capital market. There are plenty of mispricing opportunities to explore. I use quantitative models intensively to make forecasts, and most of the time, models get it right. Appealing as it is, we are not in the business of complicated math. As analysts, we advise portfolio managers and clients regularly, and most people we report to have no clue about regressions, statistical inference, stochastic process or differential equation. A hybrid of charts and models not only makes accurate forecasts but also conveys the results to others in an understandable fashion.

Models are a bit controversial in China’s capital market. On the one hand, most investment analysts in China have only the minimum level of knowledge about quantitative war chest but are nonetheless good at their jobs. It makes people wonder, why bother with complicated mathematical stuff if one can do his job with just words and charts? On the other hand, every analyst — whether rates, equity or derivatives — must have condemned the poor data quality in China at least twenty times in his career. Why bother with advanced data science if it is going to be ‘garbage in, garbage out?’

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| Source: imgflip.com |
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Those are valid concerns, but I think investment analysts, especially those who cover macro strategies and rates, should have at least undergraduate-level knowledge of statistics and mathematical modeling. I will let the result speak for itself. For all the yield curve predictions made by my models, fewer than ten percent were wrong. For all the inflation predictions made by my models, error scope never exceeded eight percent. And every prediction on the monthly marginal change of economic indicators, e.g., the interest rate will go up or down, was correct, except for one month during the Covid-19 outbreak when economic indicators were moving fanatically. From my experience, poor data quality does create problems for the more quantitative minds, but in China, we have not reached the point where data quality becomes a deal breaker. China’s capital market is still a ‘blue ocean’ for data scientists. Here are some of my takeaways on quantitative methods.

First, arguing about the accuracy of models is often pointless. In 1976, British statistician George Box penned a well-known saying in econometrics, ‘All models are wrong, but some are useful.’ In investment analysis, all we care about is prediction and making money out of predictions. It is not necessary to argue whether a model is one hundred percent economically correct. From an academic standpoint, most prediction models used at investment banks are just ridiculous. For example, prior to 2008, banks used hazard rate function and Copula method to estimate the correlation between mortgages. It probably makes no sense to a statistician, but we need to have some rough estimation on the correlation parameters to price the bonds[[1]](#footnote-2). It wasn’t ideal, but we would get nowhere if we adhered to the highest level of academic rigor. We should judge a model in investment analysis by its prediction accuracy instead of its mathematical rigor.

Second, pay more attention to the marginal change instead of the actual value. For example, if an interest rate model predicted that the 10Y treasury bond yield-to-maturity (YTM) would be 3.5% in March, but the actual average rate turned out to be 3.7% in March, it does not necessarily mean that the model is bad. If the model had predicted that the average YTM in February was 3.3% and the actual average YTM in February was 3.5%, then the model correctly predicted the marginal 0.2% change in March. Predicting the actual value is extremely hard and not always useful. It is usually the marginal change in economic indicators that shapes investment decisions. Thus, we should judge a model’s accuracy by its predictions on marginal changes.

Lastly, I keep an open mind to data mining and black-box big data algorithms but I’m cautious about these techniques. As one of my economic professors used to put it, ‘Economics is math with a story, big emphasis on the story.’ The proper way to study the relationships between economic indicators is to first use economic logics to raise a hypothesis and then use charts or models to test it. Data mining follows this process the opposite way. In data mining, we first establish a relationship between indicators, then come up with a theory to explain it. Though it is often effective for finding hidden relationships among economic indicators with data mining, any relationship that lacks sound logic in economic theories should not be used in making investment decisions.

Chapter 16: Error Correction Model

There are many time series models that we use to predict macroeconomic trends. Over the years, I found a few such models most useful. In this chapter, I will discuss the error correction model (ECM).

For investment analysts, the error correction model is handier than most other single-dependent-variable models in two aspects. First, it allows us to work with non-stationary time series, which are common in investment analysis. Most time series models require the data to be stationary[[2]](#footnote-3), and to get stationary data we often need to differentiate the time series and then lose track of the trend. In contrast, the error correction model only requires that the variables be co-integrated. Secondly, ECM captures the smooth trend in the data. Some economic variables have large, short-term volatilities that may distract us from finding the inherent trend. ECM can tame short-term noises. These two attributes are advantageous for investment analysis.

To estimate an error correction model, we start by running the augmented Dickey-Fuller test to determine whether the variables at hand are integrated. To determine the co-integrating rank, we can use the Johansen method (1988, 1991). If the test result rejects the null hypothesis of no co-integration, in favor of at least one co-integrating vector, we can proceed to estimation.

We can estimate a single equation error correction model in two stages. Readers can see clearly from the estimation method how ECM filters short-term noise. In the first stage, we fit the long-term trend and short-term fluctuations simultaneously. Let denote the economic indicator of our interest, e.g., PPI, at time *t*. Let be the vector of regressors and let be the error term. We add one lag for the regressors for demonstration. The degree of lags can be adjusted to fit different models. The following parsimonious specification is just for illustration. Specifically, we write:

where governs the dynamics of the short-term variables and governs the dynamics of the long-term trend.

The first step is to estimate the ‘fair value’ from the estimated parameters of the long-term variables. To do that, we estimate the equation above with ordinary least squares method (OLS) and obtain estimated parameters and . Then, we ‘force’ the short-term variables and errors to be zero, that is, let and rewrite the formula as:

or:

Rearranging the equation above, we can get the fair value of as:

In the second stage, we estimate the rate of convergence to the long-term fair value. To do so, we add the error correction term to the regression equation to capture the deviation from the long-term trend. The error correction term is calculated as:

Then, estimate the following equation:

If the estimated parameter satisfies , then measures the rate of convergence to the fair value. We could interpret as the share of the deviation from equilibrium that is corrected in every period.

I developed the PPI forecasting model with ECM. I assumed that in the long-run, the equilibrium industrial goods price is a function of short-run deviations, long-run real estate sales, M1, RMB exchange rate, and CRB Index (Table 16-1).

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| **Table 16-1** |
| **Regressors in the PPI Forecasting Model**   |  |  |  | | --- | --- | --- | | Indicator | Lead | Reason for Inclusion | | Real estate sales | 5 | Higher sales in real estate drive up investment and demand for industrial goods | | M1 | 6 | Higher M1 growth indicates higher level of economic activities and increases money supply | | Real Effective Exchange Rate Index | 3 | The more the RMB depreciates, the higher the procurement costs for industrial enterprises and thus the higher PPI | | CRB Index | 3 | Higher CRB index will increase the cost of industrial enterprises and lead to imported inflation |   Source: Wind Database |
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| **Figure 11-1** |
| **Predicative Power of the PPI Forecasting Model** |
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Let’s revisit Figure 11-1 to see how ECM works in reality. The dashed line is the in-sample prediction, and it is much smoother than the solid line, which is the actual historical PPI. The model can predict three months into the future, because the smallest leading period is three. We can trust our prediction if an inflection point shows up in the chart, because the prediction is smooth.

Note that between 2016 and 2018, the actual PPI was significantly higher than the predicted PPI. As we have discussed in previous chapters, this anomaly was caused by the Supply-Side Reform, in which the State Council used executive orders to drive up prices of industrial goods in order to improve profitability and wipe out obsolete enterprises.

In May 2019, the model predicted industrial deflation in the third quarter of 2020, even though PPI went up a little in May. Most analysts were confident that industrial prices were going up and the economy was recovering. The consensus back then was that the bond market was about to go bearish and we should shorten the duration of bond portfolios. Nonetheless, I decided to trust the model and advised my clients and portfolio managers that we should increase duration as industrial deflation is the early sign of floppy economic growth. Then, PPI growth rate went below zero for about half a year, and interest rates kept decreasing for almost the entire second half of 2019. Longing the bond market in May was the right decision. This was one of the times when a model beats subjective judgement. And of course, models sometimes fail, too.

Error correction model is one of the tools I like to use in making economic forecasts. The same algorithm can be applied to various purposes. It’s just a question of the variables we input.

Chapter 17: Yield Curve Model

In this chapter, I would like to introduce the model I use every month to predict the yield curve movements. I used this model to manage the duration of my account and achieved over ninety percent win rate against the benchmark index.

Understanding the dynamic evolution of the yield curve is important for allocating portfolios. A mass of literature has been developed in this field, and over the years I found the Dynamic Nelson-Siegel (DNS) model to be most effective — if we get the leading indicators right. My whole model consists of two parts. First, the DNS model lays out the mathematical structure and gives us the factors for predicting the entire yield curve. And second, we use leading indicators and the error correction model to forecast factors.

Following on Nelson and Siegel (1987), Diebold and Li (2006) introduced the DNS model to fit the term structure of interest rates. A set of *n* yields for *i*=1, …, *n* at time *t*=1, …, *N*, where is the time to maturity, is fitted in the DNS model given by:

The coefficients for *j*=1, 2, 3 are the factors that are called ‘level’, ‘slope’ and ‘curvature’, respectively. And their respective parameters, 1, , and are called factor loadings. is a decay parameter of the factor loading of the slope of the yield curve and determines the optimum of the curvature factor loadings. Notice that:

This indicates that the slope factor has a stronger effect on yields with short maturity terms. Also notice that:

This indicates that the curvature factor has a stronger effect on yields with medium maturity terms. Figure 12-1 shows how the three factors affect the yield curve at various maturity terms.

The above represents the mathematical form of the DNS model. The DNS model is useful because we can use it to predict not only the interest rates movements but also changes in the shape of yield curve, i.e., steepening or flattening. But the DNS model also has flaws. For example, we can easily prove that within the DNS formula is a monotone increasing function of maturity , which means that the yield increases as the maturity increases. But as shown in Figure 12-2, yield curves in reality have bumps and dents. This is because bonds with a maturity of three, five, ten and twenty years are more liquid than others, and thus there are ‘liquidity premiums’ on the yield curve. We can account for this by adding a fourth factor into the DNS model.

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| **Figure 12-1** |
| **How Level, Slope, and Curvature Factors Affect Rates at Various Maturity Terms** |
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In a regression model, we usually have the data for factors and estimate the parameters. But in the DNS model, it is the opposite. We know the parameters, 1, , and , and we estimate the factors, for j=1,2,3. Factor loadings were constructed to respectively simulate attributes of different maturity terms. Following that thinking, we could construct a factor loading that takes into account the liquidity premiums on the yield curve. First, we need to find an index that can measure the liquidity of each maturity. The Wind Database provides such an index, which is a weighted average of spreads, trading volume and turnover rates. Figure 12-3 shows the index.

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| **Figure 12-2** |
| **A Few Yield Curves at Different Dates**  A close up of a map  Description automatically generated  Source: Wind Database |
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Then, we use Lagrange Interpolation to construct the liquidity factor loading.

where and for *i, j*=1, …, *n* are pre-specified maturity terms and the corresponding liquidity index.

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| **Figure 12-3** |
| **Liquidity Index**  **The liquidity index shown above is calculated from numerous bonds’ Wind Liquidity Indices. Normally, bonds with longer maturity are less liquid, but we can see from the chart that five-year bonds and ten-year bonds are more liquid. These two terms have the largest trading volumes.**  **We can construct other forms of liquidity index to fit the predicted yield curves to actual yield curves. There is no right way or wrong way to do this.**  Source: Wind Database |
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Then, we improve the DNS model with the constructed liquidity factor:

Figure 12-4 presents the historical trends for the four calculated factors. In the original literature, Nelson and Siegel did not present a viable method to predict those factors. Most other literatures use autoregression models to predict the factors. While this approach might be worthwhile in academics, it doesn’t help investment analysts. Investment analysts need to find leading indicators to make meaningful forecasts. Over the years, I found a few leading indicators that we can use to predict the four factors. Table 12-1, which is the long table at the end of this chapter, presents the leading indicators that I found most useful. We can always keep trying to find better leading indicators.

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| **Figure 12-4** |
| **Historical Trends of the Four Factors** |
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To demonstrate the predicative power of this model, I will compare two charts at a given date, one for the observed yield curve movements and one for the predicated yield curve movements. Some readers may suggest that we chart the predicted ten-year treasury bond yields against the observed historical yields for a few years, but this model aims to predict the overall changes in the yield curve’s position and shape rather than the changes in a single-maturity yield. All the out-of-sample predictions of the changes in yield curve’s position and shape were correct for the past two years. But due to space limitations, I can only present one prediction in this book because a sizable graph will be generated for every forecast.

Figure 12-5 demonstrates the yield curve forecast for March, April and May 2020. The figure above is the prediction, which was made in March 2020 when the February economic data was released. The figure below shows the observed actual yield curves for those three months. Here are some key indications from the forecast figure:

* Yield curve will move down in April and then up in May. But only long-term rates will bounce back to the level in March while short-term rates will be significantly lower in May than March.

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| **Figure 12-5** |
| **Yield Curve Forecast for March, April and May 2020** |
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* Yield curve will become steeper in April and May. The curve will become steeper in April because short-term rates decrease much more than long-term rates. The curve will further steepen a little in May as short-term rates stay low while long-term rates bounce back to the March level.
* Short-term rates will be much more volatile than long-term rates. There will be a significant drop at the left end of the yield curve while only moderate changes at the right end.

The observed yield curve in the figure below confirmed those predictions. The predictions about the marginal changes in the yield curve were all correct. According to the predictions, portfolio managers should shorten the duration in March to earn a profit from the decrease in short-term rates in April and May. Also note that I did not make any prediction about the exact value of the yields, but only predicted the marginal changes in the curve’s position and shape. As we can see from above, this model has excellent predicative power and can serve as an auxiliary tool for bond duration management.

In this chapter, we discussed the model I used to predict yield curve movements. The mathematical setting was based on the DNS model and estimation was made by error correction model. The accuracy of prediction depends not only on the model formula but also on the leading indicators that we selected. Choosing the correct leading indicators requires comprehensive knowledge about the economic logic as well as industry experience. The process of looking for leading indicators is the most fun part of my job.

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| **Table 12-1** |
| **Leading Indicators for Factor Prediction**  **Slope:**   |  |  |  | | --- | --- | --- | | **Indicator** | **Explanation** | **Lead (months)** | | CPI | Consumer Price Index | 1 | | Credit expansion rate | The difference between the growth rate of central bank’s assets and the growth rate of commercial banks’ assets | 5 | | Equity risk premium | A-share’s earning price ratio minus 10Y treasury bond YTM | 3 |   **Curvature:**   |  |  |  | | --- | --- | --- | | **Indicator** | **Explanation** | **Lead (months)** | | Interbank leverage | The amount of bonds to be repurchased divided by excess deposit reserves | 3 | | Equity risk premium | A-share’s earning price ratio minus 10Y treasury bond YTM | 3 | | Housing price | 100 cities’ housing price index growth rate | 6 |   **Level:**   |  |  |  | | --- | --- | --- | | **Indicator** | **Explanation** | **Lead (months)** | | M1 | M1 Y/Y growth rate | 3 | | PMI | Purchasing Manager Index | 3 | | RMB Exchange Rate Index | RMB’s exchange rate against a basket of foreign currencies | 3 | | Social Financing | Incremental Total Social Financing (ttm) Y/Y growth rate | 3 |   **Liquidity:**   |  |  |  | | --- | --- | --- | | **Indicator** | **Explanation** | **Lead (months)** | | M1 | M1 Y/Y growth rate | 3 | | Interbank leverage | The amount of bonds to be repurchased divided by excess deposit reserves | 3 | | Shibor | 3M Shanghai Interbank Offered Rate | 3 |   Even though CPI only leads for one month, we have shown how to predict CPI three months into the future. We could then insert predicted values of CPI into the yield curve model. |
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Chapter 18: Nowcast Model

Now, my favorite part, the Nowcast Model. This part may be difficult to comprehend for readers from non-quantitative backgrounds. This model was developed to solve the problem described in Figure 18-1. Since monthly data are usually released with a lag, sometimes so long as three weeks, the reconstruction of current-month inflation and other key variables is an important task for central banks. Financial authorities devote a considerable amount of resources to figuring out the current economic status and so should investment analysts.

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| **Figure 18-1** |
| **Official Data of PPI Is Released over a Week after End of Month**    The National Bureau of Statistics releases inflation data around the ninth day of the next month. |
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To derive the monthly inflation data from multiple categories of price data, one may quickly turn to ordinary least squares (OLS) regressions. But OLS is unreliable in this scenario for three reasons. First, there are many kinds of industrial products, and throwing them all into a regression model will lead to multiple collinearity problems. If only applying the model to a few industrial products, then there is a lot of information going to waste. Second, inflation is a monthly data; while most of the prices are released daily or weekly. Linear regression cannot be directly performed on variables with different frequencies. Third, regression requires complete data, but at the time when we estimate CPI or PPI, the data set may have some null values.

So, we hope to find a way to: 1. effectively make use of as much industrial product price information as possible; 2. update monthly inflation forecasts based on weekly data flow; 3. allow for an incomplete data set and improve the prediction accuracy as the null values are gradually released. That is the Nowcast Model.

Again, this is not an econometric textbook, and I hope only to present the basic formulas. I recommend that more experienced readers refer to *Nowcasting GDP and Inflation: The Real-Time Informational Content of Macroeconomic Data Releases* (Giannone et al., 2005) for more details.

The basis of Nowcast is the dynamic factor model, which was developed by Doz, Giannone & Reichlin (2005). It is widely used by policy agencies for economic data calculation and policy development. In this framework, when we have obtained estimates of all the parameters, we can use the Kalman Filter to estimate unpublished data. I now give the mathematical expression of the model. Let’s assume that all monthly data have been interpolated to obtain the weekly sequence. There are *n*-1 variables that can affect PPI, and we construct as:

is the PPI sequence (interpolated to weekly frequency), and to are all the other variables that we think can affect PPI, e.g., weekly prices of industrial goods, purchasing manager index, etc. Also, can be very large. The first step is to reduce dimension, which is to reduce a large number of variables into just a few factors:

and are parameters, and is the regression error term. are *r* (*r*<*n*) common factors that can affect all the .

We can also use the matrix form:

Factors follow the following rule of movements:

*B* is an *r*×*q* full rank matrix. *A* is an *r*×*r* full rank matrix, and the unit roots are outside the unit circle, so that the factor sequences are stationary. is the white noise process. That is, we have *r* factors and *q* white noises in a dynamic factor system. Usually, *r* is set between seven and ten, and *q* can be set to one or two. The above is the general setting for dynamic factor model.

Now we introduce the Kalman Filter. I will skip the boring mathematical derivation and instead show you how Kalman Filter works with an example. Suppose there is a tiny robot moving on a playground. It moves with constant acceleration motion. The starting velocity is zero, and acceleration parameter is *a*.



For any given time, *t*, if the playground is perfectly smooth, then the robot’s position and velocity can be expressed as:

or

But, in reality, there are no perfectly smooth objects or perfectly smooth planes. The robot’s inherent trajectory will be subject to some interference *Q*, so the actual position and velocity will be:

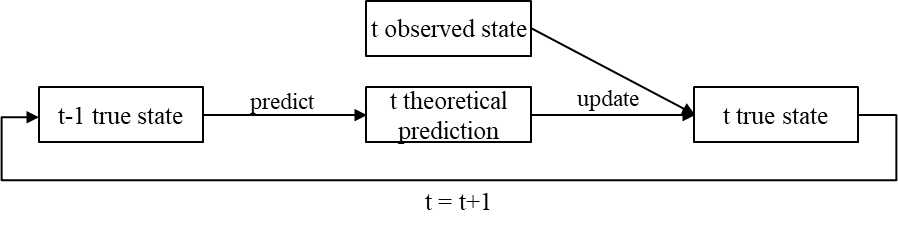
Due to the existence of the error *Q*, we cannot accurately know the state of the robot at every moment from the physics theory alone. Suppose we can observe the speed and position of the robot in real time through an instrument, but the instrument also has errors. The state we observe is not necessarily the real state. The error of the instrument is represented by *R*:

The goal of the Kalman Filter is to combine theoretical predictions and observed state to estimate hidden and unobservable true state .

The first step is *prediction*. We use the estimated true state at *t*-1 to predict the theoretical state at *t* according to the physical theory.

The second step is *update*. The theoretical value calculated in the first step is updated to the true value with the observation value at time *t*. This step requires a variable called Kalman Increment, which is expressed by .

The actual process is a bit more complicated than above. I won’t go into details about in this chapter; however, readers from quantitative backgrounds are encouraged to learn about the formulas. The process of the Kalman Filter algorithm is summarized as follow:

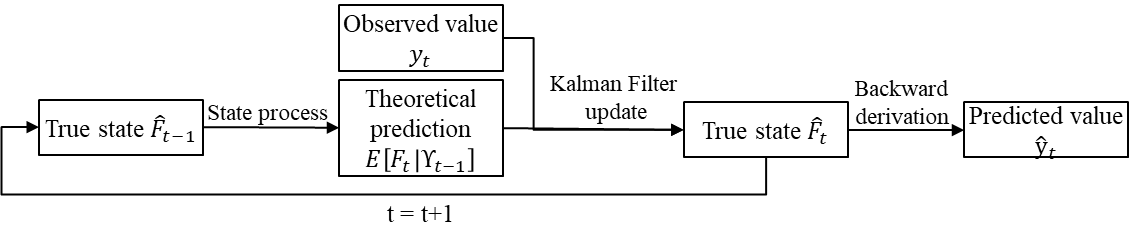


Now that we have learned about Kalman Filter, let’s look back at the dynamic factor model. We can see the hidden common factors as the unobserved true state, which can be predicted by the formula . And would be the observations of . Thus, the dynamic factor model has the structure of a Kalman Filter.

State process:

Observation process:

Let’s use to denote all known observations . Then we could use dynamic factor model to make theoretical prediction, and then update the theoretical prediction with observed values of using Kalman Filter.



Now we introduce the concept of vintage. A vintage is like a snapshot of the data set. For example, the 25 January 2020 vintage of PPI-related data looks like Table 18-1.

Vintage is denoted by . And we re-write the model:

As we can see in Table 18-1, vintage is often unbalanced, which means there are missing values in the data set. The whole point of using Kalman Filter is to fill in the missing value spots with filtered/estimated values. Here is how to deal with an unbalanced data set in Kalman Filter:

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| **Table 18-1** |
| **Sample Vintage for PPI-Related Data**   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **Date** | **PPI** | **PMI Raw Material** | **CRB** | **LPG** | **…** | **Propane** | **LNG** | | 11/29/2014 | -2.6928 | -5.3 | -1.45382 | -30.4709 | … | -21.3876 | -11.3964 | | 12/6/2014 | #N/A | #N/A | -1.76498 | -40.0594 | … | -35.5629 | -12.6241 | | 12/13/2014 | #N/A | #N/A | -2.86316 | -44.3385 | … | -37.7721 | -11.4318 | | 12/20/2014 | #N/A | #N/A | -3.34795 | -50.1729 | … | -36.3792 | -8.36489 | | … | … | … | … | … | … | … | … | | 1/18/2020 | #N/A | #N/A | -0.66557 | 14.4596 | … | 12.4335 | -22.8929 | | 1/25/2020 | #N/A | #N/A | #N/A | 13.74772 | … | 14.93063 | -20.4787 |   #N/A represents missing values and data that has not been released at the time of vintage extraction |
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This means that if a variable is null at a certain time point, Kalman Filter will not give any weight to this variable at that time point. In this way, even if part of the data set is missing, we can still calculate the factors and then use the factors to reversely derive the missing data. This is the core principle of the Nowcast technique.

To train a model, we need samples. Data of is apparently available, but what about the common factors ? To calculate the common factors, we use principle component analysis (PCA). PCA is a statistical algorithm to reduce the dimension of the vectors and make the amount of information lost to dimensionality reduction process as small as possible.

Let me give an example. Human beings are three-dimensional creatures. Taking a photograph is a process to reduce a three-dimensional person to a two-dimensional picture. When taking pictures of people, there are countless shooting angles. From some angles, we can clearly identify the person in the photo; while from other angles we can’t. Look at the following picture, this picture is the back view of a person.



Most people would not be able to tell who this is from this picture. We lost a significant amount of information by taking the photo from the back. Now, we turn the camera slightly to the right, and we get:



From this angle, we can confirm that the person in the photo is the former US president, Barack Obama. Principal component analysis is an algorithm that finds the best shooting angle so that the loss of information is minimal. We can use PCA to reduce the dimension of dozens or even hundreds of data at each time point into a few common factors .

Model training requires structural vector autoregression and EM algorithm, which I won’t go into details in this book. High-frequency data used in the inflation Nowcast are presented in Table 18-2 at the end of this chapter. All the data can be easily found in Wind Database.

The prediction results are shown in Figure 18-1. Notice that the model is less reliable for CPI comparing to PPI. This is because the components of the CPI survey basket are unknown, and the price data of the CPI basket is not as detailed as that of the PPI basket.

On 31 May 2020, my Nowcast Model predicted that M/M growth of CPI in May was -0.5%, and the M/M growth of PPI in May was -0.22%. The respective predicted Y/Y growth rates in May are 2.6% and -3.5%. At the time, market expectation for the Y/Y growth rate of CPI and PPI were 3.02% and -3.03%. Because the Nowcast predictions were significantly lower than market expectations, I advised portfolio managers to long treasury bond future at market opening on 10 June, the day when the May inflation data is released. Specifically, I advised them to long the TS2009 contract, which delivers 2Y treasury bonds on 20 September 2009, because inflation surprises have a stronger effect on short-term treasury bonds.

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| **Figure 18-1** |
| **Nowcast Results** |
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The future market opens at 9:15 a.m., and the inflation data is released around 9:30 a.m. The actual inflation data released at 9:30 a.m. were 2.4% for CPI and -3.7% for PPI, much lower than market expectation and slightly lower than the Nowcast prediction. As is shown in Figure 18-2, the treasury bond future rose to intra-day highest point quickly after the inflation data was released.

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| **Figure 18-2** |
| **Treasury Future Price Rose in Response to Lower-than-Expected Inflation Data**    The arrow points to the moment when inflation data was released. After the inflation data was released, treasury future price quickly rose to intra-day highest point in six minutes.  Source: Wind Database |
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Nowcast is a powerful tool for analysts who want to explore the errors in market expectations. It can be applied to many other economic variables such as GDP, industrial production, loans, etc. I only applied Nowcast techniques to inflation data because I detected some level of data manipulation in other economic indicators. The inflation prediction is most reliable and most useful in bond market trading.

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| **Table 18-2** |
| **High-Frequency Price Data Used in the Inflation Nowcast Model**  **PPI:**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **Energy** | **Chemicals** | **Non-ferrous metals** | **Steel** | **Food** | **Construction** | | Ethanol #93  Ethanol #97  LNG  LPG  Diesel  Gasoline #93  Gasoline #97  Coking coal Anthracite | Sulfur  Caustic soda  Methanol  Benzene  Styrene  Polyethylene  Styrene  PVC  Urea  PTA | Copper  Aluminum  Lead  Zinc  Tin  nickel | Rebar  Wire Rod  Plate  Hot rolled coil  Stainless steel  Angle steel  I-beam | Rice  Wheat  Corn  Cotton  Pork  Soybean  peanut | Cement  Steel  glass |   **CPI:**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **Food** | **Transportation & Communication** | **Healthcare** | **Alcohol** | **Office** | **Cloth** | | Pork  Beef  Lamb  Egg  Chicken  Vegetable  Fruit  Carp  Silver carp  Cutlass  Salt | Gasoline #93  Gasoline #97  Computer  Communication wire  Transportation safety | Vitamin A  Vitamin E  Vitamin D  Folic acid  Lysine  Methionine  Herbal meds | Budweiser  Harbin  Zhangyu  Changcheng  Wuliangye | Office supplies  Paper  Writing | Material  Fabric  Garment  Home textile  Accessories | |
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Appendix A: English/Chinese Comparison Table

See below the English/Chinese comparison table for key indicators in this book.

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| --- | --- |
| **English** | **Chinese** |
| 100 Large & Mid Cities Planned Construction Area | 100大中城市成交土地规划建筑面积 |
| 10Y Treasury Bond YTM | 中债国债到期收益率:10年 |
| 30 Large & Mid Cities’ Traded Area of Commercial Buildings | 30大中城市商品房成交面积 |
| Aggregate Financing to Real Economy | 社会融资额 |
| Automotive Tires Operating Rate | 开工率:汽车轮胎 |
| Average wholesale prices of animals | 平均批发价:牲畜 |
| Average wholesale prices of fruits | 平均批发价:水果 |
| Average wholesale prices of vegetables | 平均批发价:蔬菜 |
| CCFI | 中国出口集装箱运价指数 |
| China Cement Price Index | 中国水泥价格指数 |
| Consumer Price Index (CPI) | 消费者物价指数 |
| CPI Food | CPI食品项 |
| CPI Non-Food | CPI非食品项 |
| Daily Average Coal Consumption by Six Major Power Generation Group | 日均耗煤量:6大发电集团 |
| Daily Average Sales of Passenger Car | 当周日均销量:乘用车 |
| Export Delivery Value | 出口交货值 |
| Floor Space of Commercial Buildings Sold | 商品房销售面积 |
| Industrial Enterprise Profits | 工业企业利润总额 |
| Industrial Production | 工业增加值 |
| Inventory | 工业企业产成品存货 |
| Land Transaction Fees | 土地成交价款 |
| Manufacture Investment | 固定资产投资完成额:制造业 |
| Nanhua Industrial Goods Price Index | 南华工业品价格指数 |
| OECD Composite Leading Indicator | OECD综合领先指数 |
| Operating Rate of Blast Furnace | 高炉开工率 |
| Paper Financing | 票据融资 |
| PMI | 采购经理指数 |
| PMI Employment | 采购经理指数:从业人员 |
| PMI New Export Order | 采购经理指数:新出口订单 |
| Pork Price | 22个省市猪肉平均价 |
| Producer Price Index (PPI) | 生产者物价指数 |
| Real Effective Exchange Rate Index | 人民币实际有效汇率指数 |
| Real Estate Development Funds | 房地产开发资金来源 |
| Real Estate Investment | 房地产投资完成额 |
| Real Estate Investment (Construction) | 房地产投资完成额:建筑工程 |
| Real Estate Investment (Installation) | 房地产投资完成额:安装工程 |
| Real Estate Investment (Other Expenditure) | 房地产投资完成额:其他费用 |
| Real Estate New Construction Area | 房地产新开工面积 |
| Reproductive Sows Inventory | 生猪存栏:能繁母猪 |
| SCFI | 上海出口集装箱运价指数 |
| Social Consumption | 社会零售品消费总额 |
| Tangshan Steel Plant Capacity Utilization Rate | 唐山钢厂产能利用率 |

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1. Copula method requires a pre-specified parameter to estimate the joint probability of loans’ defaults. This doesn’t make sense in statistics because we need samples to estimate a parameter, but there weren’t that many defaults in the sample, and even if there were, it was impossible to control all other variables. This approach led to a severe under-estimation of the correlation among mortgages. For more details on this topic, refer to *On Default Correlation: A Copula Function Approach* (David Li, 1999). [↑](#footnote-ref-2)
2. Stationarity means that the statistical properties of a time series (or rather the process generating it) do not change over time. That is to say, the time series does not exhibit trends, seasonal patterns or any pattern that apparently differs from a random walk. [↑](#footnote-ref-3)