UNBILLED REVENUES ESTIMATION: VIRTUAL INVOICING AND MATHEMATICAL MODEL GAMMA

J. Cermakova et al.

Czech Republic

1 This paper is partly supported by research grant No. 1ET400300513 (Grant Agency of the Academy of Sciences of the Czech Republic).
ABSTRACT

Many gas companies take meter readings and consequently bill the small customers (i.e. small commercial and residential customers) periodically in approximately 12-month intervals. There is always a certain amount of gas that has been delivered to customers but has not been billed yet. As a result, the companies have to estimate unbilled revenues at the end of an accounting period. Therefore, there is a strong interest in developing a sophisticated method for unbilled supply determination and valuation. This paper discusses demands placed on unbilled revenues estimation, and summarizes experience with a technique of virtual invoicing currently used by the West Bohemian Gas Distribution Company in Pilsen, Czech Republic. The process of virtual invoicing is based on the GAMMA model; the GAMMA model estimates natural gas consumption of small commercial and residential customers. The Institute of Computer Science of the Academy of Sciences of the Czech Republic developed the model, and is further improving it in a close co-operation with the West Bohemian Gas Distribution Company with the support of a research grant awarded by the Grant Agency of the Academy of Sciences of the Czech Republic.
TABLE OF CONTENTS

Abstract
1. Introduction
2. The role of virtual invoicing and the GAMMA model
3. The process of virtual invoicing
3.1. Real vs. virtual invoicing
3.2. Process solution
3.3. Technical solution
4. Advantages and disadvantages of virtual invoicing
4.1. Advantages
4.2. Disadvantages
5. Accuracy of the GAMMA model
6. The GAMMA model’s further usage
6.1. Trading and marketing support
6.2. Distribution support
7. Conclusion

References
1. INTRODUCTION

Natural gas distribution and trade companies need detail information about their customers' behavior: about the consumptions, reaction to the actual weather conditions, seasonal character of the natural gas utilization etc. However, many companies do not measure all their customers daily or at least monthly because of technical and/or economical reasons.

In the Czech Republic, meter readings are taken once a year in case of small customers (i.e. small commercial and residential customers), for each customer in a different time depending on the meter-reading itinerary. Consequently, only a part of the total customer number (roughly one twelfth) is billed during a month. At the end of the month there is always a certain amount of natural gas that has been delivered to customers but has not been measured and billed yet, the unbilled supply. The unbilled supply has to be estimated and the related unbilled revenues as well. The companies thus face the task of applying an appropriate technique for unbilled revenues estimation; the interest in natural gas consumption modeling is growing.

Commonly accessible information about solutions to this problem abroad is scarce ([1]). In addition, the market as well as climate conditions are quite different in the Czech Republic than in other countries. Aiming to obtain accurate, exact, evidentiary and fully automated unbilled revenues estimation, the West Bohemian Gas Distribution Company in Pilsen, Czech Republic (WBG, member of the RWE Group), a front natural gas distributor and customer service provider in the West Bohemian Region, implemented a process of "virtual invoicing". The process is based on the GAMMA model, which is an unique mathematical model of natural gas consumption of small customers developed by the Institute of Computer Science of the Academy of Sciences of the Czech Republic (ICS) and being further improved in a close co-operation with WBG with the support of a research grant awarded by the Grant Agency of the Academy of Sciences of the Czech Republic.

This paper discusses demands placed on unbilled revenues estimation, describes basic principles of the virtual invoicing process and the GAMMA model, and summarizes WBG’s experience with this technique.

2. THE ROLE OF VIRTUAL INVOICING AND THE GAMMA MODEL

A continuous billing of small commercial customers and households as well as the technical type of installed measurement, which does not usually record the course of consumption between two meter readings but only the total cumulative consumption in the period, prompt the natural gas companies to look for an exact consumption model and a suitable method of unbilled revenues estimation. The request follows from nearly all activities of distribution and trade companies: purchase and sale optimization, marketing, controlling and management, distribution security and last but not least operation in the liberalized market. The unbilled revenues as of the end of every accounting period (month) must be faithfully pictured in accounting.

The unbilled supply is to be quantified periodically every month in technical units (m³, kWh) and in monetary units (CZK). It sums the supplies of individual customers from their last invoices to the balancing day, or from the contract force to the balancing day in case of a new customer. The unbilled revenues valuate both the consumed commodity (natural gas) and the capacity/fix monthly fees. The length of the unbilled supply differs for every customer since the customers were lastly billed at another time; the average unbilled supply is of approximately 190 days.

The unbilled revenues represent a substantial accounting item (the unbilled revenues of Czech natural gas companies range in order 10⁷ CZK). They appear in the balance sheet on the side of assets on the one hand, and they project onto the company's profit on the other hand. The unbilled revenues influence either the assets or profit and the income tax of a company. They are object of an annual financial audit and a possible inspection of the revenue office. Estimated accrued accounting items must follow all requisites given by law, most importantly completeness and conclusive evidence of accounting.
World experience proves unbilled revenues estimation rather delicate. Some companies had to change the method, and consequently restated the financial statements (an impact on revenues in order 10^7 USD); some were even inspected by authorities. The virtual invoicing process together with the GAMMA model has been developed to fulfill all demands placed on a first-rate and efficient technique of unbilled revenues estimation. It offers an accurate and exact way of consumption modeling correctly valued for accounting purposes. WBG first deployed virtual invoicing in October 2003. The implementation was preceded by several months of tests and trial runs. Three fiscal years, 2003 - 2005, were successfully closed with the technique.

3. THE PROCESS OF VIRTUAL INVOICING

3.1. Real vs. virtual invoicing

Virtual invoicing can be easily introduced as a fictive invoicing of estimated consumptions. Chart 1 draws a comparison between the processes of real and virtual invoicing.

**Real invoicing**

- Meter reading
- Consumption m³
- Consumption kWh
- Capacity / monthly fees
- Valuation CZK
- Invoice

**Virtual invoicing**

- Analysis of consumer’s behavior
- Virtual consumption m³
- Consumption kWh
- Capacity / monthly fees
- Valuation CZK
- Invoice

Chart 1: Comparison between the processes of real and virtual invoicing

A gas meter reading initiates the real invoicing process (chart 1, the upper scheme). Gathered readings (states on the gas meter dials) are imported to the customer information system and sent to invoicing. The consumed gas (m³) is calculated in compliance with the relative conditions (altitude, gas temperature etc.) and converted into energy units (kWh) according to the gas calorific property. Then the commodity consumption and the capacity/fix monthly fees are valued. Prices change quarterly in the Czech gas market, so the total consumption must be split up into periods with different price rates (performed linearly/non-linearly as defined in legislation).

Virtual invoicing (chart 1, the lower scheme) replaces a physical meter reading with consumption estimation. The GAMMA model is used for that purpose. The GAMMA model analyzes a known consumer’s behavior modeling the consumption for the desired period; natural gas end-uses (space heating, water heating, cooking, technologies) and the actual weather conditions are reflected ([2]). The further steps, i.e. conversion into energy units and valuation, are processed compatibly with real invoicing. Employing the technique of virtual invoicing, the unbilled supply is computed individually for every single active customer.

3.2. Process solution

Virtual invoicing is run periodically every month; its automating is necessary. WBG implemented a user-friendly module of virtual invoicing into the customer information system (CIS).

The virtual invoicing process goes through several steps: At first, a list of customers is created including all the active small commercial and residential customers. Then the model’s input data are generated and imported into the GAMMA model through a special interface; the inputs cover customer data (customer category, natural gas end-use, installed gas meters, date of the last invoice etc.), previous measured consumptions, and regional average daily temperatures. Modeled consumptions are transferred back to the CIS and virtually invoiced. Finally, reports are produced and archived.
Virtual invoicing and the GAMMA model itself serve as a useful tool for anomalies detection. Both the model’s inputs and outputs are filtered during the process in order to exclude inferior unbilled revenues estimations. Anomalies may be caused by incorrect meter readings, wrongly registered customer data, missing values etc. Marking shady values in ahead of real invoicing, early corrections are possible. As a result, a high level of the CIS data quality is maintained. The GAMMA model helps to locate customers whose consumer’s behavior is not consistent with the a priori information (e.g. the natural gas end-use contrasts with the consumption volume).

3.3. Technical solution

The GAMMA model software application stands technically as an extern application of the CIS. It is run on PC in standard MS Windows environment and does not require any special settings or extra memory capacity. The designed interfaces provide a mutual communication with the CIS (see chart 2).

The model’s inputs and outputs and the final reports are in a text format. The format allows easy browsing and working with standard software tools.

![Chart 2: A technical solution of virtual invoicing](image)

4. ADVANTAGES AND DISADVANTAGES OF VIRTUAL INVOICING

4.1. Advantages

- Fiscal and accounting evidence: Estimating the unbilled supply individually for every customer, all requisites are fulfilled following from accounting legislation, especially conclusive evidence and documentary of accounting.

- Total unbilled revenues, not an accrual: Virtual invoicing estimates the total unbilled revenues as of the balancing day; most other methods compute only an accrual.
A flexible summarization of unbilled supply/revenus: Individually figured unbilled supply/revenues can be easily added together to any required subtotals, e.g. according to price classes, customer categories, or traders. A distributor operating in the liberalized market must be able to allocate the unbilled supply to particular traders.

Cash advance analysis: Cash advance are individually comparable with unbilled revenues as a basis of trading strategy. Chart 3 illustrates the time development of unbilled revenues and advances in WBG. The unbilled supply of natural gas has a seasonal character with the peak in March and bottom in September/October. Advances are collected evenly by WBG; customers prepay higher winter consumption during the summer.

Chart 3: The comparison of unbilled revenues and advances (WBG)

Process automation: Virtual invoicing is fully integrated in the CIS with a user-friendly operation and minimum manual work.

A mathematical model: The GAMMA model provides an exact, tenable, accurate, unbiased and sustainable method of natural gas consumption estimation. The theoretical background is based on statistical theory.

The GAMMA model’s self-learning character: The parameters describing an individual customer’s behavior adapt automatically as a new meter reading becomes available.

The GAMMA model’s independence: The GAMMA model software application can connect any CIS, and besides, it can run manually outside the CIS. The manual function supports ad hoc analyses.

Compatible valuation: Estimated consumptions are valuated identically with the real invoicing. The accuracy of estimated revenues does not divert from the accuracy of estimated consumptions.

Verification of the accuracy: The accuracy of the model is verified in the calibration process. The calibration compares the last known consumption of every customer with the value estimated by the GAMMA model.
Costs on line losses: A faithful estimation of unbilled supply improves information base for line losses analysis (gas purchased but not delivered to customers), and it figures the costs on line losses that are evidentiary from fiscal and accounting views. The costs on line losses lower the income tax in the Czech Republic.

Detection of anomalies: Virtual invoicing and the GAMMA model itself detect anomalies allowing early corrections.

4.2. Disadvantages

Disposable data: High-class input data are essential for high-class output estimation. At least three years history of measured consumptions is requested. WBG has experienced that the quality of the CIS data is a crucial factor of the GAMMA model's application; an extensive half-year database cleaning preceded the implementation of virtual invoicing.

Working time: Virtual invoicing fictively invoices all small customers (the number in order $10^5$); an adequate time is needed.

The GAMMA model's maintenance: The most attainable accuracy of the GAMMA model demands a periodic actualization of its parameters (see chapter 4).

5. ACCURACY OF THE GAMMA MODEL

Accuracy of the GAMMA model is verified in the calibration process. The calibration compares the last known consumption of every customer with the value estimated by the model. Table 1 gives evidence about the accuracy of the GAMMA model. Errors are expressed relatively for customer categories and natural gas end-uses. Concrete values are influenced by class frequencies and total class consumptions.

<table>
<thead>
<tr>
<th>Customer category</th>
<th>Natural gas end-use</th>
<th>Class consumption share (%)</th>
<th>Class frequency (%)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>Space heating</td>
<td>7.8</td>
<td>4.8</td>
<td>-0.085</td>
</tr>
<tr>
<td>Households</td>
<td>Water heating</td>
<td>0.0</td>
<td>0.1</td>
<td>0.050</td>
</tr>
<tr>
<td>Households</td>
<td>Space heating + Water heating</td>
<td>10.4</td>
<td>5.6</td>
<td>-0.235</td>
</tr>
<tr>
<td>Households</td>
<td>Cooking</td>
<td>2.2</td>
<td>47.3</td>
<td>-0.006</td>
</tr>
<tr>
<td>Households</td>
<td>Space heating + Cooking</td>
<td>15.6</td>
<td>11.9</td>
<td>0.087</td>
</tr>
<tr>
<td>Households</td>
<td>Cooking + Water heating</td>
<td>1.3</td>
<td>4.7</td>
<td>-0.048</td>
</tr>
<tr>
<td>Households</td>
<td>Space heating + Cooking + Water heating</td>
<td>30.5</td>
<td>19.4</td>
<td>-0.292</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Space heating</td>
<td>17.5</td>
<td>3.1</td>
<td>0.467</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Water heating</td>
<td>0.2</td>
<td>0.1</td>
<td>0.102</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Space heating + Water heating</td>
<td>6.1</td>
<td>1.3</td>
<td>0.814</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Cooking</td>
<td>0.3</td>
<td>0.3</td>
<td>-0.765</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Space heating + Cooking</td>
<td>2.5</td>
<td>0.4</td>
<td>0.809</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Cooking + Water heating</td>
<td>0.1</td>
<td>0.0</td>
<td>-0.123</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Space heating + Cooking + Water heating</td>
<td>1.4</td>
<td>0.4</td>
<td>-1.073</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Technologies</td>
<td>0.7</td>
<td>0.3</td>
<td>-7.449</td>
</tr>
<tr>
<td>Commercial cus.</td>
<td>Technologies/Heating</td>
<td>3.3</td>
<td>0.5</td>
<td>-1.330</td>
</tr>
<tr>
<td>All Groups</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
<td>-0.067</td>
</tr>
</tbody>
</table>

Table 1: Percentage errors of the GAMMA model in customer classes (calibration as of 28.11.2005)

The errors fluctuate around zero and can be considered approximately symmetric. Any bias is recognized.
The model's accuracy is increased in part by on-line adaptation while obtaining any new meter reading, and in part by regular off-line updating of the parameters. Off-line parameters actualization optimizes the coefficients describing the general behaviors of customer classes. The process is performed quarterly; it contributes to continuous development and improvement of the GAMMA model.

6. THE GAMMA MODEL’S FURTHER USAGE

The GAMMA model has a broad applicability, mainly in the following areas:

6.1. Trading and marketing support

- Supply structure and time development profiling (technical/monetary units)
- Analysis of seasonal behavior and consumption dynamics (price elasticity, temperature gradient etc.)
- Analysis of migrations between price segments
- Marketing analysis

6.2. Distribution support

- Maximum day structure analysis
- Capacity pool control and optimization

7. CONCLUSION

Designing a sophisticated and efficient technique for unbilled revenues estimation is a rather extensive task; accuracy as well as requests given by law must be taken into account. In this contribution, virtual invoicing and the GAMMA model have been described as an effective tool.

The need for a uniform method for unbilled revenues estimation is currently discussed within the RWE Group in the Czech Republic. The co-operative research team of the West Bohemian Gas Distribution Company and the Institute of Computer Sciences believe the presented concept of virtual invoicing will be found the most suitable technique.
REFERENCES